IMPERIAL BUREAU OF ANIMAL NUTRITION

Technical Communication No. 12

RABBIT FEEDING FOR MEAT AND FUR

BY

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INTRODUCTION.

A SHORT outline of the history of rabbit farming is given in the new edition of the Ministry of Agriculture's Bulletin on rabbit keeping (182*a*). For seven centuries or more in this country rabbits have been reared in captivity, and their flesh has been highly esteemed as food, especially in winter when other fresh meat was scarce. Throughout this time they have been exploited in several European countries in times of food scarcity, but during the Great War the breeding of table rabbits was encouraged to an extent previously unknown (8, 172).

Intensive animal husbandry normally depends on a steady and abundant supply of low-priced concentrates. European countries have become increasingly dependent during the past half-century on overseas supplies of grain for animal feeding. When war interrupts such supplies the importance of stock that can be reared without concentrates becomes more obvious. In recent years rabbit production has come more and more into line with other forms of animal husbandry. Crossing has given larger and more rapidly growing breeds, and, to keep pace with the power of rapid development, feeding has become systematically intensive. It will be seen below that the rations normally used in commercial rabbit production are similar to those used for dairy and beef cattle, namely, grain, roots, hay and green food.

In a state of emergency, when the supply of feedingstuffs is restricted, two main questions must be considered : first, the relative efficiencies of different animals in converting plant feedingstuffs into animal food for man ; and second, what type of feedingstuffs each requires. It will be seen later (p. 30) that the most efficient conversion is from feedingstuffs to milk, followed by pig meat, eggs, beef, rabbit and chicken meat in that order. On the other hand, with a scarcity of concentrates, it is easier to produce milk, beef and rabbit meat than to produce pork, chicken or eggs. And, to offset its relative inefficiency of conversion, the rabbit has the great advantage over other farm animals that it can be fed solely on waste from gardens and allotments, greenstuffs from the wayside and household scraps of almost all descriptions (152, 163). It need have nothing that would, in any condition except of famine, be directly utilised as human food, and, fed in this way, its flesh represents a net gain of food of high biological value.

The market for fur now has three subdivisions. High grade pelts, including those from special breeds, go to the fur trade, and lower grade skins are used for making hatter's felt. The Angora is kept for its wool, which is clipped four times a year.

Most European countries practise rabbit keeping based on small scale breeding units. In the United States rabbits are raised in every State, primarily for meat. The total production exceeds 7 million yearly (87). In 1928 the world production of rabbit skins was estimated at between 200 and 250 millions (18). Of these over 100 millions were from Australasian wild rabbits. World production is now probably much higher. No estimate has been found of the number of rabbits reared annually in this country, but it must be considerable as in 1938 we exported, excluding re-exports, 42·3 million skins, valued at £550,000. Nevertheless, statistics of imports show that there is room for expansion even when normal supplies can be obtained. The Annual Statement of the Trade of the United Kingdom for 1938 gives the total imports of rabbit carcases as 253,571 cwt. Of that quantity 59,719 cwt. were imported fresh, 193,313 cwt. frozen and 539 cwt. tinned. This represented a total value of £433,978. Excluding the home supplies for home consumption, our trade in rabbit products totalled over £1·4 million in 1938.

GENERAL PRINCIPLES OF FEEDING.

Under natural conditions, it is stated, the rabbit generally lives on fresh or dried green food. The density of the population, like that of other wild animals, depends on the available food supply and some observers believe they have traced definite cyclical changes (19, 50, 118).

The domesticated rabbit has been found to be highly adaptable in its feeding habits, and feeding practice depends more on the nature of the feedingstuffs available than on accurate knowledge of the best type of diet. It is frequently stated that the hutched rabbit does not flourish on greenstuffs alone (160) but usually no explanation is offered. It would appear that the reason may, in part, be found in the low energy value of most greenstuffs relative to their bulk and the rapid growth of "improved" breeds of rabbits. This is in fact the same limitation as occurs with high producing milk cows. The bulk of fresh green food in each case limits the amount that can be eaten and that amount is insufficient to maintain a high rate of milk production or a high rate of growth. The restricted exercise for the hutched animal may be an important factor. Rabbits can be grazed out of doors, in runs, from weaning to killing, without additional food. On the other hand, failure to do well on a ration of hay and fresh greens, apparently adequate in energy value (see below, p. 29), suggests that such a ration is not balanced for domesticated rabbits.

Rabbits, like other mammals, cannot be maintained on diets of cereals alone. A number of restricted diets of cereals with additions of milk, cod liver oil, wheat germ oil, yeast, mineral mixtures, legumes, alfalfa, cabbage and so on, have been tested (16, 76, 78), on the same lines as early work on the mineral and vitamin requirements of rats and guineapigs, without yielding much information of practical interest. The deficiencies of a cereal diet are multiple.

Attempts to find a synthetic diet suitable for rabbits have not so far proved satisfactory (2, 77, 78, 104, 129, 135). They have yielded a certain amount of basic general knowledge of vitamin requirements and made clear the importance for rabbits of the physical quality of the diet. But these findings have not yet attained any high degree of precision. They will, therefore, not be presented in detail. The general nature of the findings is indicated below in a summary account of requirements.

Other studies of academic interest only, are that rabbits, like rats, cannot be maintained after weaning on milk alone (78), again, probably, on account of the low calorie value of milk and its low iron content, and that a diet consisting exclusively or chiefly of cabbage has resulted in the development of goitre in rabbits, as it does in other laboratory animals (12, 35, 108, 109).

DIGESTION.

The rabbit's intestine is long and the surface area of it large (14, 170). It has a well developed caecum which is the site of fibre digestion (107). For these reasons, it would be expected that the efficiency of digestion would be high. Early German work (94, 177) supported this idea, giving digestibility coefficients for rabbits similar to those for ruminants. More recent work has not confirmed these findings. Watson and Godden (175), in experiments in which the same artificially dried pasture herbage was fed to rabbits and sheep, obtained the following results :—

COEFFICIENTS OF DIGESTIBILITY OF ARTIFICIALLY DRIED PASTURE HERBAGE.

Trial	Rabbit	Dry Matter	Organic Matter	Nitrogen	Ether Extract	Crude Fibre	N-Free Extract	Feed Residues
		%	%	%	%	%	%	%
I	English No. 1	49·4	49·3	60·9	23·9	28·7	56·2	0·67
	English No. 4	48·1	48·0	60·8	22·8	26·1	55·7	11·43
	Havana No. 3	45·6	45·1	58·4	21·9	21·3	53·2	0·31
	Silver Dutch No. 2	49·8	49·5	64·3	21·5	27·0	56·6	0·74
II	English No. 4	50·9	50·9	63·1	32·9	27·6	57·9	2·71
	Havana No. 3	49·0	48·9	61·5	32·0	25·2	56·0	0·51
Average for rabbits		48·8	48·6	61·5	25·8	26·0	55·9	
Average for 2 sheep		74·3	77·2	76·7	51·8	74·5	81·4	

Although the herbage of mixed grasses and clover cut in August was of only 5 weeks' growth, and therefore not specially fibrous, only a small proportion of the fibre (26 per cent.) was digested by the rabbits. The presence in the intestine of large quantities of undigested fibre appeared also to depress the utilisation of the other constituents, protein being least affected. Other studies with artificially dried pasture clippings (150), in which it was found that digestibility decreased when the proportion of " stemmy " material fed was high, give similar indications.

With freshly cut grass and kale, Watson and Horton (176) got better results. The digestion of fibre was 50 per cent. and that of the other constituents correspondingly higher. Yet in this series also rabbits differed significantly from sheep in their power to digest fibre and again, in the studies with grass, the total utilisation was low in comparison with sheep, or compared with the utilisation of kale by either rabbits or sheep.

COEFFICIENTS OF DIGESTIBILITY OF GRASS AND KALE FED TO RABBITS AND SHEEP.

	Dry Matter	Organic Matter	Crude Protein	True Protein	Ether Extract	Crude Fibre	N-Free Extract
	%	%	%	%	%	%	%
Grass Sample 1 Rabbit	63·40	63·68	78·95	76·97	45·86	46·88	67·25
Grass Sample 1 Sheep	77·66	80·72	80·96	79·59	55·47	83·97	81·18
Grass Sample 2 Rabbit	63·02	63·69	76·74	74·83	41·02	50·12	66·84
Grass Sample 2 Sheep	73·10	76·47	77·18	72·52	45·85	78·39	77·52
Grass Sample 3 Rabbit	62·75	62·95	76·23	74·00	51·18	50·96	64·86
Grass Sample 3 Sheep	72·18	76·03	75·77	74·14	55·10	78·25	76·53
Marrow-stem kale Rabbit	82·92	82·66	86·44	83·62	72·10	54·93	88·00
Marrow-stem kale Sheep	81·74	85·03	88·03	83·94	68·44	74·32	84·46

Brüggemann (22) has made digestibility trials with some commonly used rabbit foods. The average results, to the nearest whole number, are as follows :—

Coefficients of Digestibility of Some Rabbit Foodstuffs.

	Organic Matter	Crude Protein	True Protein	Crude Oil	Crude Fibre	"Carbo-hydrates"
	%	%	%	%	%	%
Oats . . .	64	79	79	90	18	72
Wheat . . .	94	81	80	92	90	97
Barley . . .	90	78	80	90	72	93
Steamed potatoes .	98	58	54	100	100	99
Meadow hay . .	47	60	63	43	18	64
Lucerne hay . .	61	76	74	16	39	73
Nettle hay . .	63	96	90	32	42	79
Green lucerne .	81	89	87	71	66	88
Maize silage . .	55	79	37	96	24	69
Mangolds . .	97	66	36	—	100	96

These results support the conclusion that the digestibility of herbage plants decreases as they become more fibrous. They also indicate that, although the small amount of fibre in roots may be completely digested, the protein is less well utilised than that of herbage ; and that oats are less well digested than either wheat or barley. This might be attributed to the higher fibre content of the oat husk.

In agreement with these results, Walworth (171) found the digestibility of the dry matter of a typical mixed ration to be about 70 per cent., and that of the fibre to be only 28 per cent.

Recent attempts have been made in Russia (148) to increase the digestibility of fibre by chemical treatment. Treatment of rye straw with chlorine dioxide gave a significant increase in digestibility.

From all these data, the following tentative conclusions may be drawn : (1) the higher the fibre content of a food, the less efficient is the utilisation ; (2) digestibility coefficients determined with ruminants are not strictly applicable to the calculation of rabbit rations. This will be true especially of the herbage part of rations. It follows that calculations of the starch equivalent of rations from the usual tables of composition of feedingstuffs will tend to overestimate the nutritive value for rabbits. In Watson and Godden's experiments the dried pasture used had a S.E. for sheep nearly twice that for rabbits. On the other hand, the nutritive ratio of the pasture was 1 : 2·6 for rabbits and 1 : 3·6 for sheep. Since the utilisation of protein is affected by excess fibre less than that of other constituents, the nutritive ratio for rabbits of fibrous foods will be narrower than would be indicated by the usual values.

REQUIREMENTS.

Energy.—The basal (or standard) energy requirements of rabbits of different weights have been determined (13*a*, 97). In mammals the energy requirement per unit body weight varies inversely with the body size and, hence, since the rabbit is the smallest farm mammal, its energy requirement is relatively the highest. The basal requirement for 24 hours of a rabbit weighing 1 kg. is roughly 62 Cals. ;* of one weighing 2 kg., 51 Cals. per kg. ; 3 kg., 47 Cals. per kg., and so on, decreasing to 43 Cals. per kg. at 6 and 7 kg. body weight. The corresponding requirement of a 500 kg. cow varies from 12 to 17 Cals. per kg. according to

* A Calorie is the unit used in the measurement of heat or energy expenditure. 1 g. of "starch equivalent" yields 4·1 Calories.

diet, and that of a 500 kg. bullock is only about 13 Cals. per kg. body weight. Hence the basal energy requirement of the rabbit, per kg. body weight, is rouhly 3 times that of cattle. It is slightly lower than that of fowls. There does not appear to be any difference between different breeds such as Angora, Blue Beveren and Chinchilla (165).

Basal energy requirement is determined when the animal is, as nearly as possible, in a condition of complete rest, neither moving nor even digesting or absorbing food. Hence, to determine maintenance requirement, an addition must be made to cover the energy expenditure on eating, drinking, digesting and the other ordinary activities of living. No scientific measurement has been made of this expenditure in the rabbit and, in practice, the amount of food allowed is determined empirically by reference to weight, condition and appetite. The only theoretical standard applicable would be that proposed by Brody (20) for mammals in general; namely, that the energy value of the total digestible nutrients for maintenance should be of the order of twice the basal requirement.

Since practical rations are devised purely on an empirical basis (102, 144), it is of interest to see how such rations conform to theoretical standards. Such comparisons can be made only to a very limited extent because the calculations of energy intake should be based on digested nutrients and determinations of digestibility have been made on rabbits only with a small number of foodstuffs. Using the results of the digestibility trials quoted above, the following comparisons have been made :—

(*a*) Ration : dried grass fed *ad lib.* (Watson and Godden, 175.)
Average energy value of digested nutrients daily : 218 Cals. Average weight of rabbits, 2·32 kg.
Average energy value per kg. body weight, 94 Cals.
Theoretical basal requirement, 50 Cals. per kg.
Ratio 1·8 : 1. Theoretical ratio required 2 : 1.

(*b*) Voinov's (168) maintenance ration of 600 g. fresh greenstuff for a 3 kg. rabbit.
(1) As fresh lucerne : Brüggemann's coefficient of digestibility (22)
Intake 420 Cals. per day = 140 Cals. per kg.
Basal requirement 47 Cals. per kg. Ratio 3 : 1.
(2) As kale : Watson and Horton's coefficients of digestibility.
Intake 252 Cals. per day = 84 Cals. per kg.
Basal requirement 47 Cals. per kg. Ratio 1·7 : 1.
A mixture of 2 parts kale to 1 part lucerne would provide roughly the theoretical requirement.

(*c*) Swedish maintenance ration (61) for a 3 kg. rabbit of hay, oats and fodder beet (see p. 20) using Brüggemann's coefficients of digestibility.
Total daily energy value, 300 Cals. = 100 Cals. per kg.
Basal requirement, 47 Cals. per kg.
Ratio 2·1 : 1.

Other maintenance rations, such as II and III in Table 1 (p. 19), when their energy value is calculated, not from actual determinations on rabbits but from conventional tables of composition of feedingstuffs, give ratios of about 1·8 : 1, in agreement with example (*a*). Walworth (171) states that a rabbit of 7½ lb. (3·4 kg.) weight requires 0·32 oz. (9 g.) starch equivalent per lb. That is equivalent to 81·4 Cals. per kg. and again gives a ratio to basal requirement of roughly 1·8 : 1. Tomme and Loria (165) allow 24 g. starch equivalent per kg., giving a ratio to basal of 2·1 : 1.

It will be seen, therefore, that these rations centre in energy value round the theoretical requirement of twice the basal metabolic rate. They do not appear to err on the generous side. It has been stated (57) that in practice the amount of food required for maintenance varies considerably. Increases would be expected in cold weather and if the animals were very active.

It is more difficult to discuss the adequacy of production rations, but illustrative attempts may be of interest.

For production of any kind, additions must be made. Brody considers that the energy requirement of the lactating cow, excluding the energy value of the milk and any gain in weight, is of the order of 2·4 times basal. For growth and fattening, the energy value of the food used for weight gain, *i.e.* a multiple of the energy value of the weight increase, must be added. From analyses of carcases, the energy value of 1 g. increase in weight during growth is of the order of 1 Cal. and, during fattening, of the order of 1·75 Cal.

The total energy requirement for growth is the sum of the requirements for maintenance and gain in weight. The requirement for maintenance at different stages is approximately known and, if it were also known for the rabbit what ratio the energy of the food used for weight increase bears to the energy of the product, standards could be elaborated for all stages of growth and fattening. This ratio can be determined only from the results of experiments in which the total digestible nutrients consumed and the rate of growth are known. Lack of suitable recorded data makes the calculation of theoretical standards impossible at present.

Nevertheless, it may be useful to call attention to the following point. Walworth says that for production of fur, flesh or fat, 0·66 oz. starch equivalent is required per lb. live weight. This is equivalent to 169 Cals. per kg. live weight. The theoretical requirement can be expressed in the form of an equation :

$$\text{Total calorie requirement} = a \times \text{calories in product} + \text{calories for maintenance.}$$

If this standard be applied to rabbits of 1 kg. weight, gaining weight at the rate of 23 g. daily and if the calorie value of the gain is approximately 1 Cal. per g., the equation becomes :

$$169 \text{ Cals.} = a \times 23 + 124$$

and the ratio of production calories to weight increase calories is 2 : 1. In the same way, if it be applied to rabbits of 2 kg., gaining 14 g. daily, the ratio is 9·6 : 1 and for rabbits of 3 kg., putting on fat at about 2 g. daily, the calorie value of the product being about 1·75 Cals. per g., the ratio becomes roughly 60 : 1.

These calculations are, of course, very rough but they show that this standard appears either to imply a very high efficiency of utilisation of digestible energy in the young rabbit or to leave an unnecessary surplus for the rabbit approaching full growth. A standard expressed as starch equivalent per kg. body weight ought probably to be graded down from this or higher, for rabbits up to 1 kg., to a considerably lower level for fattening. King Wilson's experimental findings that the rate of weight gain in young rabbits can be increased by more generous feeding than is usual, but not that of older animals (see below, p. 14), appears to support this view.

It may be taken that, on the average, well fed does produce about 35 ml. milk per kg. body weight. The energy value of rabbit's milk may be from 170 to 200 Cals. per 100 ml. Hence, a doe weighing 3 kg. would require from 510 to 540 Cals., and one weighing 2·5 kg., from 440 to 470 Cals. daily.

Voinov's ration for does of 700-900 g. greenstuff and 40-60 g. concentrates would yield, as 700 g. lucerne and 40 g. oats, 588 Cals., or as 900 g. kale and 60 g. oats, 525 Cals. The Harper Adams stock ration (Table 2, No. 1) gives an energy value per day of 450 Cals., using ordinary feedingstuffs analyses. The former rations are, therefore, suitable for 3 kg. and the latter for 2·5 kg. does.

Protein.—The protein requirement is usually expressed by means of the "nutritive ratio," which is another way of saying the proportion of energy derived from protein. For example, a nutritive ratio of 1 : 4 means that 20 per cent. of the calories are from protein. Brody, on the basis of protein minimum experiments, deduces a generalised maintenance requirement for adults of 10 per cent., *i.e.*, a nutritive ratio of 1 : 9. The requirement for production will depend on the protein content of the product.

The maintenance requirements suggested on the basis of practical experience are from 1 : 8 to 1 : 10 for fully mature animals but for young adults or stock going into production, ratios of 1 : 4 to 1 : 7 are recommended (28, 46, 132, 133, 171). In the course of his digestion experiments, Brüggemann showed that the rabbits fed on meadow hay, with a nutritive ratio of 1 : 6, were in N equilibrium.

The protein requirement of suckling rabbits as shown by the composition of rabbit's milk is from 1 : 1·6 to 1 : 3·8. From weaning onwards, the ratios required will decrease gradually to the adult level. Those usually recommended vary from 1 : 3·5 to 1 : 5 (7, 29, 46, 60, 132, 133, 171), but Templeton, in an experiment in which rabbits of large breeds were allowed to choose their own food, found that both does and young selected food giving ratios between 1 : 2·66 and 1 : 3·00 (161). This is close to the average composition of the milk. It should be remembered that the change from suckling to other food means a change to protein of lower biological value, and the proportion of protein should not be too rapidly reduced. Macdonald recommends a ratio of 1 : 4 for early growth and lactation.

Cultivated pasture in the early stages of growth has so high a protein content that its nutritive ratio resembles that of milk and no additional protein is required even for lactation. The fibre content is also low and therefore utilisation by rabbits would be high. Uncultivated pasture, on the other hand, has a much lower protein and a much higher fibre content. In feeding trials with rabbits in which cultivated pasture was shown to be of much superior feeding value to unfertilised pasture, it was also found that the addition of protein, as casein, and the amino-acid cystine, to the unfertilised pasture raised its feeding value almost to that of fertilised grass. The part, if any, played by cystine, in this improvement, was not separately determined.

Chemical analysis has shown wool to be rich in the amino-acid cystine, which cannot be built up in the body but must be supplied in the food. It has therefore been thought that deficiency of this amino-acid might interfere with wool growth and extensive experiments have been made with sheep. In one experiment with rabbits, in which cystine was added to a ration of low cystine content (whole oats, broad bran, flaked maize, hay and turnips), there was no definite effect on yield of wool (10). Although one experiment is certainly not conclusive, recent work on sheep supports the view that deficiency of cystine is not likely to occur in practice.

Fibre.—Experiments with synthetic diets have shown that the rabbit requires a certain proportion of fibre in its diet but studies of the digestion of food by the rabbit have shown also that a high proportion of fibre reduces the utilisation of the other components. This has been discussed above. It seems possible that the value of fibre may have been over-stressed in the past and that too much may sometimes be provided, for instance, in rations containing large proportions of hay, especially if the quality is poor, or by feeding old rank grass in summer, the effect being most marked in growing and lactating animals.

Vitamins.—A diet deficient in vitamin A produces in rabbits the usual symptoms of keratinisation of mucous membranes, keratomalacia and xerophthalmia. Under natural conditions the rabbit derives its vitamin A from green food in the form of the precursor, carotene, but the vitamin itself in butter, cod liver oil (but cf. below, p. 10) or concentrates can be utilised (127, 128, 129). Rex rabbits appear to have a higher requirement than other breeds (125, 126, 196).

Vitamin B deficiency appears to be unknown in the rabbit although observations (82) indicate that abnormal maternal behaviour, desertion of the young and cannibalism, may be associated with deficiency of some part of the vitamin B complex since addition of yeast to the diet reduced the incidence of such behaviour. Passmore (135) failed to produce symptoms of vitamin B_1 deficiency with a synthetic diet, adequate in other respects. He suggested the possibility that coprophagy might be responsible but added that it had not been observed. Since then, it has been established that rabbits normally practice

coprophagy (160*a*) and the failure to produce symptoms of deficiency is probably due to synthesis of vitamin B_1 by micro-organisms in the gut.

Rabbits are not highly sensitive to deficiency of vitamin C but scurvy can be produced experimentally (116, 117) and many experienced workers regard a supply of vitamin C all the year round as essential.

Vitamin D is of importance to practical rabbit farmers. In the absence of sunshine, and especially if the calcium or phosphorus intake is inadequate, vitamin D is required to secure proper calcification of the bones and teeth (55, 116, 117, 122). Rex-furred rabbits are more liable than other breeds to suffer from rickets (126, 192, 194). As sources of vitamin D, egg-yolk, cod liver oil and vitamin D concentrates are effective but care must be taken not to give too much cod liver oil (167), since high doses produce a characteristic disease described below, or concentrate which may produce toxic symptoms (72, 73, 84, 85, 86). A daily dose of 0·5 ml. cod liver oil for a young rabbit is adequate. Various proprietary preparations have been used with success (23, 126).

On artificial diets deficient in vitamin E or diets in which vitamin E has been destroyed by chemical treatment (121), rabbits develop muscular dystrophy, a deficiency disease characterised by paralysis due to degeneration of muscle tissue. A similar condition follows the feeding of too much cod liver oil. It is not certain that the missing substance is identical with vitamin E and the exact nature of the action of cod liver oil has not been determined. The injurious effect of high doses of cod liver oil is probably of more practical importance in rabbit rearing than deficiency of vitamin E since there is no rigorous demonstration that, in the absence of vitamin E, the rabbit is infertile. Yet Italian workers claim that addition to the diet of substances rich in vitamin E improves both fertility and general condition. In one case (106) the original diet and the quantities of the supplements fed are not described ; in the other (157) 6 ml. of wheat germ oil per head daily were added to a ration of maize meal, hay and cabbage. The dose was therefore so high as to suggest that the effect may have been due to the oil rather than to the vitamin E it supplied (see below, p. 30). No effect was produced, in preliminary experiments, by small doses. Since food intake was not measured and there was no control group with an equivalent amount of oil without vitamin E, these results must be received with caution.

Minerals.—From general experience of the feeding of farm animals, it would be expected that salt would be required by rabbits as a regular addition to plant feedingstuffs and that many rations would be improved by the addition of calcium. Salt is frequently given in America but otherwise little account appears to be taken of mineral requirements.

Calcium.—The high rates of reproduction and growth of the rabbit make it apparent that heavy demands are made on the calcium supplies of the doe during lactation. To supply the material for growth of the young, the mineral and especially the calcium and phosphorus contents of rabbit milk are high, about five times those of cow's milk. Studies of blood calcium (74, 80, 112) indicate that calcium metabolism in the doe is readily affected by environmental conditions, including diet, and suggest that reproduction may make heavy demands on the doe's reserves. These demands may be so high as to cause serious depletion, for Wilson (194) has shown that when rickets occurs in the young it is usually in fourth or later litters and usually in large litters. After weaning, the continued high rate of growth of the young makes it necessary that their rations should be rich in calcium.

In practice, if the proportion of green food in the ration is high, severe deficiency is not likely to occur. Some rations include milk or fishmeal. These are given usually as sources of protein, and they are also important sources of calcium. It is known that addition of calcium to grain rations has beneficial results, but no tests seem to have been made to show whether supplements to ordinary mixed rations, not containing either milk or fishmeal, would be beneficial. Nor is either the minimum or the optimum level of calcium intake for health known. There is room here for experimental work.

Iron and Copper.—It is probable that young rabbits suffer, like other sucking animals, from a physiological anaemia liable, in the absence of sufficient supplies of iron, to become acute and to form an important cause of mortality. But few studies of anaemia in the rabbit have been found, possibly because the custom of giving green food would prevent gross deficiency. Nor have studies of copper requirement been made but deficiency is not likely to occur unless in the few areas where the herbage is known to be deficient in copper. It has been noted that administration of large amounts of copper will cause pigmentation and cirrhosis of the liver (62, 63).

Iodine.—The addition of iodine to the diet has been recommended to improve health and coat lustre, and is frequently practised with that in view. Corrie (41) considers 8 grains of potassium iodide yearly (1·4 mg. of iodine daily) to be sufficient. Much larger doses have been fed to growing rabbits without ill effect (180) but, since large doses may cause diarrhoea and emaciation, and since, in pregnant does, abortion may occur, care should be exercised in the use of iodine. For instance, no diet already supplemented with cod liver oil or fishmeal is likely to require any further addition of iodine.

Sulphur.—Sulphur, which has long enjoyed the reputation of having beneficial effects on the skin and coat of animals, is sometimes given, but improved results have not been demonstrated. From work on other animals, it is unlikely that inorganic sulphur would be utilised and we have already seen that the addition of sulphur in organic combination as cystine, to a ration such as would be fed in practice, had no significant effect.

Salt.—The question of salt (NaCl) requirement has been considered last because it is intimately connected with water metabolism. Lack of an adequate supply of salt causes loss of water from the body, low rate of growth, low milk production, and the health and condition of animals is profoundly affected. The utilisation of food is impaired. Indeed, the effect on condition generally and on the coat in particular is so marked that it is surprising that more studies of the salt requirements of rabbits have not been made.

It is well known that herbivorous animals have a "salt hunger" and, under natural conditions, seek out "salt licks" to satisfy their craving. Observations made at Canberra (40) indicate that the rabbit is no exception.

The tolerance of rabbits for salt is high. This has been shown by Gompel *et al.* (56, 57) in experiments in which the food was made into a mash with salted water. When the salt concentration exceeded 10 g. per litre, no other water being allowed, the food was at first consumed with reluctance and when the salt exceeded 25 g. per litre the food was rejected. If the concentration was gradually increased, the rabbit acquired tolerance and readily took food containing up to 35 g. per litre. When the concentration exceeded 4 g. per litre, and unsalted water was offered, the water consumption increased in such a way that the final concentration of the salt in the food was always less than would depress food consumption. The maximum daily quantity taken, without increasing thirst, was about 0·3 g.

Only one record has been found of the voluntary consumption of salt by rabbits. Templeton (161*a*) measured the salt consumption of New Zealand rabbits fed on concentrates and hay with a small allowance of greenstuff and a salt lick. Ten mature males consumed on an average 0·088 lb. yearly (or 0·88 per cent. of their own liveweight) and 43 females with their litters, 0·195 lb. yearly. This is equivalent to 0·1 g. daily for the males and 0·24 g. daily for a doe with litter.

In North America salt is commonly added at a level of from 0·25 to 0·5 per cent. of the total ration (29) or as 1·0 per cent. of the mash.

In the absence of further information as to the salt requirement of rabbits, it would probably be best to provide a salt brick, as is done for cattle and sheep, from which they can satisfy their requirement (59).

Water.—More than two-thirds of the weight of the newborn rabbit, and approximately two-thirds of the adult, is water (199). Water is constantly lost from the body in the excreta

and through the skin. It must, therefore, constantly be replaced. The requirement will be increased in hot weather. Rabbits kept in the sun lose from 12 to 23 g. of water per hour as compared with 2 to 3 g. per hour in the shade (*74a*). The milk yield of does may be as high as 180 g. daily and maintenance of milk yield is impossible without a corresponding supply of water.

Among rabbit keepers there are two schools of thought regarding the need for water. Many breeders of old fancy varieties say that water is unnecessary ; some even say it is harmful. Yet experimental studies and practical observations clearly indicate that, unless large quantities of fresh green food are being fed, additional water is required. Wirth (200) found that Angora rabbits, deprived of water, showed loss of appetite and a 20 per cent. fall in wool production, and Christian (36) that a diet of dry mash, 150 g., and green food, 100 g., without water, caused death from impaction of the caecum. When water was given, 80 to 120 ml. were taken daily.

Brüggemann (22) has measured the water consumption of 5 adult rabbits on different rations. The results are summarised below :—

Foodstuff	Water Contained in Food	Additional Water Drunk	Total Water Intake
	ml.*	ml.	ml.
Meadow hay	11	156	167
Lucerne hay	17	144	161
Nettle hay + steamed potatoes .	156	—	156
Green lucerne	235	—	235
Maize silage + meadow hay .	96	12	108
Oats	12	101	113
Barley + meadow hay . .	19	142	161
Wheat + meadow hay . .	19	121	140
Mangolds + meadow hay . .	202	—	202
Steamed potatoes + meadow hay	160	—	160

* 1 pint = 568 ml.

Rabbit	No. 1	No. 2	No. 3	No. 4	No. 5
	ml.	ml.	ml.	ml.	ml.
Average daily water consumption .	126	148	118	188	200
Range of variation	100 to 173	123 to 197	102 to 178	125 to 228	148 to 248

In spite of the considerable variation in the amount consumed by each rabbit, it may be deduced that rations of steamed potatoes or mangolds and hay provided enough water under the conditions of the experiment ; fresh green food more than enough, and that dry rations of grain or grain and hay required the addition of about a quarter of a pint of water daily.

Yet rabbits, even on fresh green food only, will drink water and there seems to be no good reason why it should not always be provided. From observations at the Harper Adams College, where this is the custom, it is believed that there would be less cannibalism and urine drinking if this practice were generally adopted.

Reference has already been made to the close correlation between salt and water metabolism. No statement is made that salt was fed in Brüggemann's experiments. It should be noted that, without an adequate supply of salt, water cannot be retained in sufficient amounts in the body. On the other hand, if too much salt is given, the water requirement will be increased. It is best, therefore, to supply both, independently of the food, and to allow the animals to adjust to their own needs the intake of each.

DIET AND HEALTH.

It is well known in animal feeding that growth is most rapid and production highest when health is best : it is equally true that, when growth and production rates are highest, health is most difficult to maintain. It has been shown that adequate supplies of energy, protein, certain vitamins and minerals, especially calcium and sodium chloride, and water are necessary. Since green food supplies protein, vitamins and minerals in relatively large amounts, and grain foods supply energy with relatively little of these other substances, it follows that deficiencies are much more likely to occur with winter rations than during the summer and to affect the growing stock and breeding does more than resting adults. In practice, it is commonly found that litters born in the autumn do not thrive like those born in spring in this country.

The conditions leading to impaction of the caecum and paralysis have not been fully investigated but the chief factor appears to be failure to supply sufficient water.

From experience with other animals, it would be expected that insufficient feeding, and deficient diet, would affect resistance to infective disease. There can be no doubt, for instance, that deficiency of vitamin A would reduce resistance to certain bacterial infections. The observation that " snuffles," a disease of the respiratory passages, has been cured by giving cod liver oil (83) may be an example, but there is little evidence to show of what practical importance such deficiencies are in rabbit farming (3, 11). Underfeeding is said to result in a high mortality from coccidiosis and a study of disease and mortality in large stocks would probably show other important correlations with diet. Burky (25) considers that weight records give a reliable indication of clinical condition.

In addition to these main considerations, dangers to health arise from the use of damaged foods (113, 198) or the presence in foods of poisonous substances (21), and from the use of foods infected with the organisms of disease to which the rabbit is susceptible. Such foods include milk containing tubercle bacilli (111) and eggs infected with *Bact. pullorum* (131, 151), *i.e.*, from fowls with bacillary white diarrhoea.

SIZE AND PRODUCTION.

Adult Weight.—Different breeds of rabbit vary more in adult weight than any other type of domesticated animal. Hence, any general standardisation of feeding practice on an age basis is impossible and all rationing must be planned with reference to the size and rate of growth or production of the breed in question.

The entire range in adult weight appears to be from about 2 to 20 lb. (201). The small Polish breed averages about 3 lb. and the Flemish Giant, 10 lb. or more. The breeds usually reared in this country attain weights of from $4\frac{1}{2}$ to 8 lb. These differences are not due to feeding (although they may be affected by it) but are hereditary (32, 33, 95, 103, 138, 149, 191). A table, showing breed characteristics and " standard " weights, is given in the Ministry of Agriculture Bulletin (182*a*). [In some other countries breeds of the same names are bred to a heavier standard weight than in this country.]

Rate of Growth.—The difference in time to reach adult weight is relatively less than the difference in adult weight ; that is to say, the large breeds grow more rapidly than the small.

For instance, at 180 days of age, medium-sized breeds, such as Angora and Havana, weigh 4 lb., and giant breeds about $5\frac{1}{4}$ lb. Yet, according to Robb (154) the percentage growth rates are the same for all from the smallest to the largest breeds. If this is so, then it would be legitimate to express feeding standards as so much per lb. or per kg. live weight.

The following data from Hammond (70) illustrate the effect of litter size on the rate of growth of the young :—

No. of young suckling .	1	2	3	4	5	6	7	9
Av. weight of young at 3 weeks (g.) . . .	448·0	478·1	429·0	321·1	315·5	286·4	295·4	192·4
Av. weekly growth at 3 weeks (g.) . . .	134·0	170·2	146·2	76·4	79·9	76·4	88·4	20·9

It will be seen that litters of 3 or less grew much more rapidly than litters of from 4 to 7, and that when there were as many as 9 young suckling, growth was seriously retarded. It should also be noted, however, that the total liveweight of a litter was at a maximum when the number of young was 7. Closely similar data are given by Hagelin. Since these differences must have been due to differences in milk supply per head of the litter, the importance of rationing for an abundant flow of milk is obvious.

Numerous studies of the rate of growth of young rabbits have been made (89, 90, 91, 92, 124, 161, 193). Neglecting the effect of litter size, it is conventionally stated that the young should double their birth weight within a week. The maximum rate of growth is said to occur at different times from 4 to 7 weeks.

The following table shows the recorded growth rate for Chinchilla rabbits (61). These figures are given as optimum for well-fed rabbits in litters of 6. Growth rate recorded in these litters is considerably higher than that shown in the graphs in the Ministry of Agriculture Bulletin (182*a*) for large numbers of medium-sized rabbits :—

Growth Rate of Chinchilla Rabbits.

Days from Birth.	Total Weight, g.	Gain per Day, g.
0–14	60–225	11·8
14–30	225–400	10·9
30–45	400–700	20·0
45–60	700–1050	23·3
60–75	1050–1400	23·3
75–90	1400–1750	23·3
90–105	1750–2000	16·7
105–120	2000–2200	13·3
120–135	2200–2350	10·0
135–150	2350–2500	10·0
150–165	2500–2650	10·0
165–180	2650–2750	6·7
180–195	2750–2825	5·0
195–210	2825–2875	3·3
210–225	2875–2925	3·3
225–240	2925–2950	1·7
240–450	2950–3000	0·2

King Wilson (186) considers that the growth rate in early life can, by suitable feeding, be increased above that usually attained, but that, later, a higher plane of nutrition than

usually recommended will not produce appreciably better gains. This is in agreement with what was said above, p. 8, regarding the generalised standard for growth, which appears to be low for young rabbits and in excess for the higher body weights.

Fangauf and Immenkamp (51) have made a detailed study of growth and food consumption in 3 rabbits of each of 9 breeds. No indication was found that any one breed utilised food more economically than another. Growth was practically complete, under the conditions of the test, in small breeds at 5 months, in medium breeds at 6 months and in large breeds at 7 months. German " standard " weights for show purposes are said to be higher than can be obtained with economical feeding.

Reproduction and Lactation.—In the pregnant rabbit the weight of the foetus is only 3 g. at 20 days but from 20 to 30 days it increases, on the average, by 44 g. and the birth weight is affected by the feeding of the doe during the last 10 days of pregnancy (69). Fattening should be avoided, since it produces smaller, instead of larger young, but the ration must be adequate to ensure satisfactory birth weights and good milk production.

An extensive study (15) of milk production on Bertelli's breeding farms has shown that yield depends on diet. During the first 5 days, yield varied from 25 g., which was usually insufficient to keep the young alive, to 180 g. which gave excellent growth. On the average, the daily yield, during the height of lactation from the 12th to the 25th day, was about 35 g. per kg. liveweight. The maximum weight of the rabbits studied was 4 kg.

Yield began to decline about the 30th day. The period of effective lactation did not exceed 45 days. Bertelli reckons that the total yield for a lactation should be not less than 2·4 litres and it may be much more. According to calculations by v. Wendt (178) a Silver Fox doe rabbit, weighing less than 6 lb., which reared a litter of 10, must have produced at least 100 g. of milk daily, *i.e.*, 5·6 litres for an 8 weeks' lactation. This is roughly equivalent to a yield of 10 gallons daily for a cow. Another doe (90) produced in 4 litters within a year 19 young weighing 66·4 lb. at 8 weeks.

The following tables show the composition of rabbit milk, as given by different authorities, and compared with cow's milk. The very high protein and mineral contents of rabbit milk (65) are associated with the rapid rate of growth of the young. Since the concentration of nutrients is so much higher than in cow's milk, and yield at the height of lactation is also very high, it follows that the lactation requirements of the rabbit are relatively much higher than those of the cow. This is recognised in practice. Illustrative calculations have already been presented.

PERCENTAGE COMPOSITION OF RABBIT'S MILK.

Investigator or Authority	Water	Protein	Fat	Sugar	Ash	Days to Double Birth Weight
Bunge (24)	—	14·4	—	—	2·5	—
Abderhalden (1)	—	10·4	—	—	2·4	7
Pizzi (145)	69·4	15·5	10·5	2·0	—	—
Dakin (45)	—	10·1	8·7	9·0	—	—
	—	14·3	33·0	2·0	—	—
Tocher (164)	69·50	15·54	10·45	1·95	2·56	—
Wendt (178)	—	10·5	16·7	2·0	2·5	6
Morris (123)	69·50	12·00	13·50	2·00	2·50	—
Butterfield (27)	—	11·4–15·0	12·1	1·8	2·50	6
Davies (47)	—	10·38	16·71	1·98	—	—
Cow's milk	87·27	3·39	3·68	4·94	0·72	47
Goat's milk	86·88	3·76	4·07	4·64	0·85	19

Butterfield (27) gives detailed mineral analyses as follows :

	Potassium	Sodium	Iron	Calcium	Magnesium	Phosphorus	Total Ash
	%	%	%	%	%	%	%
Rabbit's milk .	0·209	0·147	0·0014	0·637	0·033	0·435	2·50
Cow's milk . .	0·147	0·072	0·0015	0·119	0·014	0·083	0·70

It is interesting to note the close similarity between the mineral composition of the 2-week old rabbit and of rabbit milk (136).

Percentage Content of Inorganic Constituents.

	Potash	Soda	Lime	Magnesia	Iron Oxide	Phosphoric Acid	Chlorine
Rabbit's milk .	10·1	7·9	35·7	2·2	0·08	39·9	5·4
14-Days-old rabbit	10·8	6·0	35·0	2·2	0·23	41·9	4·9

Wool Production.—Young Angoras are first clipped at 8 weeks of age, and then regularly 4 times a year for 4 or 5 years. For the first year, the wool yield is about $5\frac{1}{2}$ oz., for the second, about 7 oz. and thereafter $8\frac{1}{4}$ to $8\frac{1}{2}$ oz. annually. This represents a growth of only about two-thirds of a gram of wool daily, and it would not be thought that wool production would make any significant demand on food supply. But the experiments to be described below (p. 29) show that changes in a maintenance ration may gravely affect wool yield and that, with young rabbits, diets which curtail liveweight increase by about 30 per cent. during the first 260 days, may limit the wool clip to 50 per cent. of that in well-fed controls.

CHOICE OF FOODS AND METHODS OF FEEDING.

The two main considerations governing the choice of foods ought to be, to secure a balanced ration from the available foods, and to keep the cost of feeding as low as possible. The possible choice of foodstuffs is wide (48, 54, 59, 66, 162).

The " available " foods vary from one country to another. For instance, in Italy the rotation of fresh food is as follows : in summer, alfalfa, vetches, soya bean, cabbage, artichokes, elm leaves and Indian millet ; in autumn, cabbage, carrot, beetroot ; in winter, clamped green food, beetroot, carrots, swedes ; and in spring, Indian millet, rape seed, cabbage, alfalfa and vetch.

In Hawaii rations consist mainly of weeds, green crops and shrubs, including the wild pea-bean, sweet potato vines and branches of koa haole (37). In Sweden branches of pine and juniper are a staple winter fresh food and, indeed, are recommended all the year round (61). In America and this country, where intensive rabbit farming is practised, the " available " foods include all the usual farm feedingstuffs (17, 81, 143). But it has already been noted that waste materials, such as the trimmings from vegetable crops, the tops of root crops, kitchen waste and many weeds are good food for rabbits. Lists of green foods for rabbits are given by Bell (13).

Green Food.—An almost endless variety of plants may be used to supply green food. In intensive practice, however, where large quantities are required daily, the tendency is to

replace natural herbage by cultivated crops, especially in winter, and to use roots as partial substitutes for green, leafy food. In view of the difference in composition of these two types of food, however, it should be remembered that when roots are used, the supplies of calcium and protein for growing and lactating stock require to be made up from other sources. To maintain a regular supply of green and root crops, the following schedule has been found satisfactory at Harper Adams College (190) :—

January :	Swedes, mangolds, thousand head kale or cabbage.
February :	Mangolds and kale.
March :	Mangolds, kale and early grass or weeds.
April :	Mangolds if necessary, kale, grasses, red clovers and weeds.
May :	Grasses and red clovers.
June :	Grasses and red and white clovers.
July :	Grasses and red and white clovers, and kale thinnings.
August :	Grasses and clovers, and kale thinnings or outer leaves.
September :	Grasses and clovers and kale (main crop).
October :	Kale or other *Brassicae*.
November :	Marrowstem kale and swedes or carrots. Wilted sugar beet tops (free from soil).
December :	Kale and swedes or carrots.

Some large producers use beet pulp (71, 96, 100) and potatoes are extensively used on the Continent (79).

With regard to the use of herbage, it should be remembered that fibrous material is not well digested or utilised. With such material, weight and dry matter do not give a reliable guide to nutritive value. Experiments in which the nutritive values for young rabbits of manured and unmanured pasture were compared showed that the rabbits fed on fertilised grass (air-dry, with 1 per cent. of salt) grew much better than those on unfertilised pasture. When supplements of casein and cystine were added to the unfertilised pasture, the two became approximately equal in value (43). The same worker also found (42) that dried timothy gave better results than dried reed canary grass as the sole diet of growing rabbits.

Hutched rabbits do not maintain condition, or grow at the normal rate (see below, p. 29), on a ration of greenstuff and hay alone. It has been seen above that the utilisation of hay is poor and that excess of fibre depresses the utilisation of other constituents of the ration. On the other hand, it is difficult to explain why both adult and growing rabbits in outdoor runs on good growing herbage should grow as well as intensively fed hutched stock (147). It appears that exercise may play an important role.

For high production, *i.e.*, rapid growth or high milk yield, the energy value of herbage is too low. Since the nutritive ratio, especially of young leguminous crops, is very narrow, a supplement of energy-yielding food is required to balance the ration.

Concentrates.—A great number of studies have been made to compare the nutritive value for rabbits of different cereals and of seeds used as sources of protein. In America, maize was rated as of slightly higher value than oats, wheat or barley, which were graded in that order. (This is not in agreement with the results of Brüggemann's digestibility trials.) Soya bean meal, moistened, was found to be about 10 per cent. better than peanut meal, dry soya bean meal or linseed oil meal. On the other hand, when rabbits were given free choice of cereals or of oil seeds, the orders of preference were : oats, wheat, barley ; peanut, soya bean, sesame, linseed, cottonseed and hempseed.

It is impossible to describe all the tests that have been made with different combinations of the common cereals, milling offal and protein concentrates. Examples will be found in the rations tabulated below. In addition to oilseeds and legumes, other protein concentrates used with success are milk, fresh or dry, fishmeal, meatmeal and meat- and bonemeal, and, for particularly rapid growth of giant breeds, chopped fresh meat has been used (173). It is important to remember that plant protein concentrates other than legumes, and meat without

bone, supply very little calcium and that, therefore, a supplement of Ca will be required unless a large part of the ration is green food, and probably even with some kinds of green food.

Methods of Feeding.—When green food is intended to form a large part of the ration, it should be wilted (99) before feeding in order to reduce the bulk.

Pelleting the concentrates eliminates wastage but early attempts to feed rabbits on pelleted rations broke down on account of impaction paralysis (36). This is obviated by provision of green food and water, and pelleted concentrates, in spite of their high cost, are now extensively used by rabbit farmers in California. All-mash rations, even with green food, have not been found suitable for young rabbits (134).

The number of feeds given daily varies. Adults are usually given two, young rabbits three or even four (93).

The dry matter content of a ration determines to some extent the amount that will be eaten. Ashbrook (4) states that a breeding doe requires daily $\frac{1}{2}$ to $\frac{3}{4}$ oz. dry matter per lb. liveweight.

MAINTENANCE RATIONS.

In practical rabbit farming, maintenance usually implies more than merely maintaining a stationary body weight. A healthy adult rabbit continues to make small weight gains during most of its breeding life. Further, practical rabbit farmers usually require "non-productive" animals to improve in condition as a preparation for breeding or require them to grow new coats of wool. Hence, a rabbit that merely maintains its weight is not, under normal conditions, adequately nourished. It should be noted, therefore, that, theoretically, maintenance rations for stock expected to improve in body condition or clipped for wool should exceed the true maintenance requirement. It has been seen above (p. 8) that Walworth's allowance of starch equivalent for fur and flesh is roughly double his maintenance allowance, but that the Harper Adams' allowance of starch equivalent for Angoras which were being clipped for wool (ration III, Table 1) is, on the theoretical basis, only a maintenance ration. Small increases in body weight were, however, obtained.

The following rations are in use at different centres :—

Medium-Sized Rabbits—Angora, Havana, etc.

In small scale experiments with Angoras, Paice used a daily ration of oats $2\frac{1}{2}$ oz., swedes 3 oz., and milk 4 oz. No hay was given, but wheat straw was used as bedding and, on the assumption that 2 oz. of the straw were consumed daily, the nutritive ratio of the ration was 1 : 7, the starch equivalent 2·64 and the daily consumption of dry matter was approximately 4·7 oz. The rabbits throve on this allowance. If milk was omitted the ration of swedes was increased to 8 oz. and 1 oz. of bran was added. The nutritive ratio was now from 1 : 7 to 1 : 8, the starch equivalent 2·71 and the daily consumption of dry matter 5·6 oz. This ration was criticised by breeders for the omission of hay. A ration of greens 8 oz. and mash 3 oz. (made up of sharps 2, boiled potatoes 1 and bran 1) would have a nutritive ratio of approximately 1 : 5, and if 8 oz. of roots were substituted for greens when these were scarce the ratio would be approximately 1 : 7. The following mashes each has a nutritive ratio of approximately 1 : 4·5 : (A) weatings 2 parts, bran 1 part ; (B) bran 2 parts, Sussex ground oats 1 part ; (C) Sussex ground oats 2 parts, bran 1 part, bean meal 1 part. If the bean meal is omitted from the last mixture the ratio becomes 1 : 6.

An extensive series of rabbit feeding tests with fur and wool breeds has been carried out by King Wilson at Harper Adams College (182, 183, 184, 185, 186, 195). For maintenance, two feeds were given daily : dry mash and either poor hay or green food in the morning and grain and green food in the afternoon. In winter, oats partly replaced the greenstuff. Various ratios of dry food to green (or root) foods have been used as shown in Table 1. The general recommendation arising from these trials for the maintenance of medium-sized rabbits is 1 oz. of dry mash, $\frac{3}{4}$ oz. of oats, 2 oz. of hay and 4 to 12 oz. of green food or roots daily.

When green food is plentiful the amount of dry foods is reduced and greenstuff increased from 8 to 15 oz. When green food is scarce the hay allowance is increased.

The mash used in the stock diet of Table 1, excluding Lot L, consisted of 40 per cent. yellow maize meal, 40 per cent. Sussex ground oats, 10 per cent. wheat bran, and 10

TABLE 1.

MAINTENANCE RATIONS.—*Average Daily Food Consumption of "Medium" Sized Rabbits.*

Group No.	Breed	No. of Rabbit Feeding Days	No. of Rabbits	Time of Year	Dry Mash	Oats	Hay	Greens or Roots	Total per Rabbit	Av. Initial Liveweight*	Av. Final Liveweight*
					oz.	oz.	oz.	oz.	oz.	lb. oz.	lb. oz.
I	Angora†	2,400	20	April—Sept.	0·837	1·019	0·981	1·006	3·843	5 4·1	5 7·5
II	Havana	5,010	30	Dec.—May	0·990	1·049	1·117	0·841	3·997	5 5·2	5 9·2
III	Angora†	15,040	32	All times	0·977	0·862	0·812	1·599	4·250	4 4·0	4 10·5
IV	Lilac	588	14	May—June	0·86	0·81	1·24	1·62	4·53	5 5·0	5 10·0
V	Angora†	616	14	April—June	0·714	0·130	1·172	3·099	5·115	5 3·0	5 13·0
VI	Angora†	2,016	18	Oct.—Feb.	1·075	1·403	1·833	1·666	5·977	5 0·0	5 6·6
VII	Havana	1,848	11	Sept.—Mar.	1·078	0·950	1·143	2·941	6·112	4 15·5	5 9·2
VIII	Angora†	4,322	20	July—Feb.	0·743	0·661	2·061	4·538	8·003	4 10·0	4 13·5
IX	Havana	4,480	20	July—Feb.	0·818	0·746	2·125	4·658	8·347	5 3·2	5 8·7
X	Angora†	4,425	17	Mar.—Dec.	1·126	1·179	1·106	5·495	8·906	5 6·29	5 0·1
XI	Angora†	7,280	20	All times	1·14	1·00	0·28	8·17	10·59	4 13·3	5 3·9
XII	Angora†	18,200	50	All times	0·664	0·499	0·140	10·574	11·877	5 4·4	4 11·0
XIII	Angora†	1,512	9	Sept.—Mar.	1·291	1·119	0·464	11·484	14·358	4 4·0	5 1·0
Range					0·664 to 1·291	0·130 to 1·403	0·140 to 2·125	0·841 to 11·484	3·843 to 14·358		
L	Angora†	7,280	20	All times	1·88	—	0·30	8·46	10·64	4 12·2	5 1·4

* After a 14-hour fast.

† The Angoras were clipped for wool production.

per cent. white fishmeal, freshly mixed at intervals of not more than 1 month. For Lot L (189) the mash was made of bran 62·5 per cent., sharps 12·5 per cent., barley-meal 12·5 per cent., white fishmeal 6·25 per cent., and linseed 6·25 per cent. This replaced

both the control mash and the grain. Owing to the bulky nature of this dry mash with its high bran content, consumption by Lot L was slightly lower than by the control group. At the end of one year's feeding the bodyweight was almost identical with that of the controls but condition was slightly inferior. In another test bran replaced the mash portion of the control ration, and at the end of one year's feeding the bran group had lost an average of 2 oz. liveweight while the controls had gained an average of 13 oz.

At the Kiel-Steenbek Poultry Research Institute (153), Angoras are given hay *ad lib.* all the year round. In winter they have also 50 g. daily of a mixture of equal parts of middlings, oatmeal and soya bean meal, 50 g. boiled potatoes and 200 g. turnips. In summer, they have 250-300 g. of green food. On these rations in one trial they gained over 1 lb. in weight and the wool clip was about 10 oz. in a year. In a second trial, the weight gain was about 2 lb. and the average clip about 13 oz. in a year.

Swedish rabbit rations are based (61) on a maintenance requirement of about 0·8 food unit per kg. liveweight monthly, or for a rabbit weighing 3 kg. 0·08 food unit daily.* In summer, a ration of green food only is given. During the transition from winter feed to green feed, hay is provided. Later in the season, 50 g. of oats are given on alternate days until winter feeding starts. The following tables show first the daily allowance of different green foods and then different types of winter rations, all calculated for a 3 kg. rabbit. It should be noted that the figure giving digestible protein in clover hay in these rations is much lower than would be expected from analyses of clover hay in this country and are comparable with the usual figures for poor meadow hay.

1. Daily Alternatives: Green Food Only.

Green Food	Daily Ration	Dry Matter	Food Units	Digestible Protein	Ash	Vitamins
	kg.	g.		g.	g.	
Clover at beginning of flowering	0·560	110	0·08	9·52	8·96	A, D, B, C
Lucerne at beginning of flowering	0·600	120	0·08	12·60	13·80	A, D, B, C
Clover grass mixture . .	0·520	120	0·08	7·80	11·96	A, D, B, C

The lowest protein, 2·6 g. per kg. liveweight, is adequate for maintenance.

2. Winter Ration with Fodder Beet.

Food	Daily Ration	Dry Matter	Food Units	Digestible Protein	Ash	Vitamins
	g.	g.		g.	g.	
Clover hay .	85	70·5	0·034	3·56	4·85	A, D, B, C
Oats . . .	40	34·5	0·033	3·08	1·24	A, B
Fodder beet .	125	15·0	0·014	0·50	1·25	A, B, C
Total . .	250	120·0	0·081	7·14	7·34	

Oats and drinking water in the morning, hay and beet at night.

* Swedish food unit is 1 kg. of barley of average quality or its equivalent.

3. Winter Ration with Oat Straw.

Food	Daily Ration	Dry Matter	Food Units	Digestible Protein	Ash	Vitamins
	g.	g.		g.	g.	
Oat straw . .	60	51·0	0·014	0·54	3·42	?
Oats . . .	30	26·0	0·025	2·31	0·93	A, B
Wheat bran .	40	34·6	0·032	4·52	2·08	A, B
Soya bean meal .	5	4·4	0·006	2·05	0·03	A, B
Carrots . .	50	6·5	0·006	0·25	0·50	A, D, B, C
Total . .	185	122·5	0·083	9·67	6·96	

This ration is somewhat low in vitamin D, but this can be corrected by giving cod liver oil with the oats. The wheat bran and soya bean (finely ground) should be well mixed with 90 g. water. The carrots and oats should be given in the morning, the mash and straw in the evening. The wheat bran may be replaced by approximately the same weight of oatmeal.

Roots should accompany hay in the late winter when the vitamin C content of the hay is probably low. If roots are not available, large branches of fresh pine and juniper can be used instead, and indeed should always form part of the winter ration.

4. Winter Ration with Potatoes.

Food	Daily Ration	Dry Matter	Food Units	Digestible Protein	Ash	Vitamins
	g.	g.		g.	g.	
Clover hay .	70	58·0	0·028	2·95	4·01	A, D, B, C
Oats . . .	40	34·5	0·033	3·08	1·24	A, B
Potatoes—raw .	75	18·8	0·019	0·68	0·83	A, B, C
Total . .	185	111·3	0·080	6·71	6·08	

The oats and drinking water are given in the morning, the hay and potatoes in the evening.

It has already been noted that adjustments are made in the choice of foodstuffs so as to utilise those produced locally without any real difference in the nature of the rations fed. For instance the following grain mixture is used on one of the most important rabbit farms in the Argentine (49) : bird seed 30, broken maize 30, bran 15, oats 15, guinea corn 9 and salt 1 per cent. Pasture and forage plants and roots are fed as elsewhere.

Giant Breeds.—At Metz (98), in experiments with Blue Beveren and Géant Normand rabbits, the following maintenance rations were used in spring and summer : in the morning oats or boiled barley 30 g., bran 10 g. ; at noon, 50 g. fresh grass ; in the evening, hay 40–80 g. and fresh pasture 100 g. From November to April, the rations were : roots 1 00 g. and oats 10 g. or bran 50 g. in the morning, and, in the evening, 40 g. hay, 10 g. barley and 10 g. oats.

The German Agricultural Society (52) recommends rations for summer consisting of 20 g. grain and 60 g. hay with 250 g. potato peelings (as mash) or 350–400 g. greens. In winter, they suggest rations of 20 g. cereal or soya bean meal with 60 g. hay and 100 g. carrots, or 60 g. hay and 100 g. carrots along with kitchen offal, or 200 g. potatoes with 30 g. bran and various herbs.

The Belgian Ministry of Agriculture (120) recommends for summer feeding as much green fodder as will be eaten without waste in addition to 20 g. oats and 50 g. of a meal

mixture consisting chiefly of bran and including one-sixteenth of its weight of meatmeal. In winter, a ration is recommended of 50 g. of the meal mixture, hay and roots (carrots or swedes) and a little linseed occasionally.

In the United States of America a series of feeding tests has been made, mainly with the large New Zealand breed, intended primarily for table purposes. In California, very small amounts of fresh green food (*e.g.* 10 per cent.) and up to 60 per cent. of high grade alfalfa hay and large proportions of concentrates are used. The following concentrate mixtures are recommended there (6) :—

Ration	A	B	C	D	E	F
	lb.	lb.	lb.	lb.	lb.	lb.
Oats (rolled) .	100	—	—	100	40	25
Oatmeal . .	—	—	100	—	—	—
Wheat (cracked or whole) . .	35	100	50	25	—	25 rolled
Wheat bran (red)	—	—	50	75	25	—
Barley (rolled) .	100	33	—	—	20	—
Maize (cracked) .	35	33	30	25	—	25
Linseed meal .	10	—	8	—	—	—
Peanut oil meal .	—	4	—	—	14	—
Soya bean meal .	—	—	—	—	—	24
Bonemeal (odourless) . .	—	—	—	—	1	1
Black strap molasses . .	—	—	—	25	—	—

Mixtures E and F are generally recommended, as each has a nutritive ratio of 1 : 3·89, which is similar to that of alfalfa hay, so that variations in the proportions of hay and concentrate do not change the ratio. Peanut and soya bean meals can be interchanged, but linseed meal has only five-eighths the nutritive value of these two as a protein supplement. Hence, in order to maintain the nutritive ratio at the same level with linseed meal, the proportion of the meal must be suitably increased. It is good practice to supply daily 2½ oz. or more of hay, 1 to 2 oz. of grain and a salt lick. At the Rabbit Experimental Station in California it was found that to maintain a mature New Zealand buck at proper weight for a year required 30 lb. of grain and 115 lb. of hay, under this system of dry feeding.

Tables of the estimated requirements of different live weights have been compiled by Charon (34).

High Condition.—The extensive show system for exhibition rabbits demands the maintenance of high condition with a well-developed coat. Rations similar to those already described supplemented with protein are used for maintaining these conditions. Successful methods of feeding and management are described in handbooks on the subject (119, 159). Milk in some form, but preferably fresh whole milk, is the most extensively used supplement, owing to its beneficial effect on body and coat condition. Milk improves the gloss on the coat by doubling the amount of fat present in the hair. Oil cakes or seeds, especially linseed, are also used for this purpose. Raw eggs, or egg flip (174) (*i.e.* a raw egg beaten up in milk with sugar to sweeten) are popular. Sulphur and other supplements are sometimes used as well as various stimulants and, occasionally, drugs. In America, Fowler's Solution has long been used in fitting animals, such as horses, for showing (155), in the belief that it aids in the production of fat and glossy hair. As the active ingredient of this solution is potassium arsenate an experiment was carried out on rabbits to determine whether the compound has any harmful effect on health and reproductive powers. Rabbits weighing from 2 to

3 kg. were given 0·75 ml. of the solution daily and smaller rabbits received smaller doses. In adult rabbits fertility was reduced and in their young mortality was increased, although the growth of survivors was unaffected. The solution was found to have harmful effects and to retard growth when administered to the young. Rabbits to which the solution was administered became lethargic and fat.

PRODUCTION RATIONS.

Lactating Medium-Sized Rabbits.—On account of the low energy value relative to the bulk of green food, it is not generally possible to devise production rations of green food only. Still, if the foodstuffs are properly chosen and cut at the early stages of growth, when fibre is low and protein content high, rations may consist chiefly of greenstuff. McDougall (110) fed 0·5 lb. daily early in the season, increasing the amount to 1 lb. and maintaining this level as late as October.

The following table shows the amounts of greenstuff and concentrates used in Russian experiments (99) :—

For Pregnant Does (2½ to 3 kg.)		For Same Does Lactating		
	Fresh Greenstuff		Fresh Greenstuff	Concentrate
	g.		g.	g.
1st to 10th day .	550 to 650	1st month . .	700 to 800	40
10th to 20th day .	600 to 700	Afterwards for two weeks . . .	800 to 900	60
20th day—kindling	650 to 750	—	—	—

Rations for Young Rabbits	Fresh Greenstuff.	Concentrates
	g.	g.
6 weeks to 2 months . .	220 to 250	20 to 25
2 to 3 months . . .	300 to 350	25 to 30
3 to 4 months . . .	400 to 450	30 to 35
4 to 5 months . . .	500 to 550	25 to 30

The greens are wilted and given in three feeds.

In mixed rations, it has not been usual to make any alteration in the nature of the foodstuffs used for production but the proportions are sometimes changed and additional protein supplements may be necessary. At the Harper Adams College, the stock diet used for maintenance rations (Table 1) was used also for production but the mash allowance was slightly and the green food allowance greatly increased. An extra feed of greenstuff was given to lactating does at mid-day.

Various combinations and proportions of foods have been tried experimentally and these are shown in Table 2. Instead of hay, dried grass may be used for production. It is readily eaten.

When the protein supplement of the control mash was altered from 10 lb. fishmeal to 5 lb. fishmeal plus 7½ lb. dried skimmilk for breeding does in autumn and winter, it gave no better results. Fresh kale was fed in both cases.

In Sweden also maintenance rations are used for breeding does, the quantities being gradually increased until they are doubled. If the protein and vitamin contents are low in the

TABLE 2.—Daily Rations for Breeding Does, at Harper Adams College.

Lot	No. Used	Breed	Dry Mash	Oats	Hay	Greens or Roots	Daily Total	Mash Used Dry
			oz.	oz.	oz.	oz.	oz.	
1	30	Various	1·08–	1·02–	0·82–	4·72–	7·64–	
			1·99	1·93	2·33	5·35	11·60	Control
2	30	Various	1·52–	1·05–	0·82–	3·15–	6·54–	
			2·81	1·95	2·13	5·44	12·33	Milk mash
3	30	Havana	1·11	1·17	1·14	1·70	5·12	Control
4	12	Havana × Rex	1·79	2·00	—	4·67	8·46	,,
5	11	Havana × Rex	1·47	1·31	—	11·23	14·01	,,
6	9	Lilac × Rex	1·70	1·67	0·10	7·73	11·20	,,
7	6	Angora	1·76	0·90	—	13·74	16·40	,,
8	6	Angora	2·71	—	—	14·22	16·93	Linseed
Range . .			1·08–2·81	0·90–2·00	0·00–2·33	1·70–14·22	5·12–16·93	

Mashes for Breeding Stock.

	Control Mash	"Milk Mash"	"Linseed Mash"
	lb.	lb.	lb.
Bran	10	10	50·00
Sharps	—	—	18·75
Barleymeal . . .	—	—	18·75
Sussex ground oats . .	40	40	—
Maize meal (yellow) . .	40	40	—
Linseed	—	—	6·25
Fishmeal	10	5	6·25
Dried skimmed milk . .	—	7·5	—

maintenance rations (*e.g.* rations 2 and 4, pp. 20–21), the parts richer in protein and minerals should be increased more than the rest of the ration. The following table shows types of summer and winter rations fed in Sweden.

The method of feeding the summer ration is to give hay *ad libitum* in racks, and freshly cut clover morning and evening. In winter the morning feed consists of oats and carrots, or oats and whole milk, the remainder of the ration being given in the evening. With the root ration, the hay and concentrates are made into a mash with 250 g. water. With the milk ration no water is required but bran and oatmeal are well mixed with skimmed milk and fed with hay; this ration is claimed to give optimum winter milk production from breeding does.

Alternatives to the usual root ration are obtained if the carrots are replaced either by 180 g. fodder beet or 80 g. potatoes, plus fish liver oil to provide vitamins A and D, or by 150 g. marrowstem kale, 140 g. silage, or even pine or juniper *ad libitum*. No fish liver oil is said to be needed with these replacements.

The winter ration with roots is suitable for production. Quantities should be gradually increased until, at 40 to 60 days of age, they are doubled.

	Rations for Summer	Rations for Winter.	
	Hay and Greens	With Roots	With Milk
	g.	g.	g.
Clover, fresh	1590	—	—
Carrots	—	170	—
Hay, clover	300	230	200
Oats	—	150	150
Oatmeal	—	50	50
Bran	—	60 *	60
Soya bean meal	—	10 *	—
Fishmeal	—	10 *	—
Milk, raw, whole	—	—	60
,, skimmed	—	—	200
Total, daily	1890	680	720
Dry matter	567	460	375
Food units	(0·347)	(0·348)	(0·347)
Digestible protein	39·6	41·6	38·9
Ash	42·5	26·3	22·7

* Or equivalent weight of mixed ground grains.

Generalised standards for maintenance, pregnancy, lactation and fattening, given by Legendre (98), are shown below.

STANDARDS FOR RABBITS WEIGHING ABOUT 2½ KG.

	Concentrates	Hay	Greens or Roots
	g.	g.	g.
Maintenance	60	80	225
Pregnant does or suckling, first month	70	135	300
Suckling does, second month	100	300	675
Fattening	80	50	250

(For animals weighing 3½ kg., increase by 25 per cent.)

In France, the maintenance rations already described of bran, barley, oats and roots are used for pregnant does in winter but the hay allowance is doubled and an extra feed of 50 g. of milk and 100 g. carrots is given at noon. In spring, the lactating does are given the maintenance ration plus 10 per cent. for each youngster suckling up to 1 month and 25 per cent. more for each youngster from 1 month until weaning.

The Belgian Ministry of Agriculture also uses the same ration as for maintenance but the oats allowance in summer is increased to 50 g., and the meal mixture to 250 g. both in summer and winter.

Lactating Giant Breeds.—In the United States a considerable number of experimental studies have been made on the feeding of lactating does (29, 89, 92, 158, 161). At Kansas State College (115) the following mixed concentrate was fed nightly to lactating does and on alternate nights to growing young, with good results :—

Ground oats 25 lb., alfalfa meal 20 lb., ground maize 50 lb., linseed oil meal 5 lb., bran 5 lb., tankage 3 lb., bone ash 2 per cent. and salt 0·25 per cent.

Butterfield and Lloyd (29) state that their practice is usually to allow nearly 1·5 lb. of alfalfa hay to each lb. of grain, but that the ratio is sometimes 1·2 : 1. During the first 2 weeks after parturition the normal daily ration of a 10 lb. doe is 5 oz. of hay plus 4 oz. of concentrates. The grain allowance is later raised to 8 oz. plus the needs of the young (total 18 oz. for the doe and litter), and the hay allowance is eventually trebled. The ration of green food, if any, is not stated. Elsewhere, Butterfield (28) enumerates typical Californian mixtures for breeding does and young growing rabbits. These are fed with high quality alfalfa hay.

Food	I	II	III	IV
	%	%	%	%
Rolled barley or Fine cracked maize	70	20	85	—
Wheat bran	15	15	10	15
Linseed meal or Soya bean meal	15	—	5	—
Dried skimmed milk	—	5	—	—
Dried beet pulp	—	—	—	25
Salt	0·25	—	0·25	0·25
Digestible protein	12·8	12·9	10·5	8·2
Total digestible nutrients	76·2	76·8	76·6	74·0
Nutritive ratio	1 : 5	1 : 5	1 : 6	1 : 8

At the Michigan Experiment Station, Connolly and Card (38) used the following basal ration with alfalfa hay in a series of small-scale feeding experiments :—

> Bran 25 parts, ground oats 20, maize meal 15, ground barley 15, dried milk 10, gluten meal 5, bonemeal 1, charcoal 0·5, cod liver oil 0·5, and salt 0·25.

The following table shows the average daily food consumption of a breeding doe (New Zealand) and litter of young to weaning age (158). The ration consisted of 40 per cent. concentrates and 60 per cent. alfalfa hay :—

Daily Ration for Breeding Doe (lb.).

	Before Mating	After Parturition	Doe and Litter			
			2 Weeks Old	4 Weeks Old	6 Weeks Old	7½ Weeks Old
Concentrates	0·16	0·24	0·32	0·60	0·92	1·16
Hay, alfalfa	0·24	0·36	0·48	0·90	1·38	1·74

In Los Angeles rabbit farm production studies (26), based on yearly records of 5711 does, the average food consumption of a " breeding doe unit," including her progeny, was found to be : grain 55·0 lb., mash (and pellets) 153·2 lb., greens 132·0 lb., hay 131·8 lb., these being the amounts required to raise an average of 15·7 young of total weight 58·8 lb. Expressed in terms of food consumption for each lb. of rabbit successfully reared the figures were : grain and mash 3·5 lb., greens 2·3 lb., and hay 2·3 lb.

Canadian feeding methods (30, 130 and 156) are a compromise between English and American practice.

Growth.—Table 3 shows a number of daily rations used at the Harper Adams College for growing rabbits of medium-sized varieties up to 4 and to 10 lunar months of age:—

TABLE 3.—Daily Rations for Growing Rabbits (Medium-Sized Varieties). Average Daily Food Consumption. (1 Period = 28 Days.)

Group	Breed	No. of Rabbits Used	Food	1st Period	2nd Period	3rd Period	4th Period	5th Period	6th Period	7th Period	8th Period	9th Period	10th Period
				oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.
A	Lilac × Rex, F_2	30	Mash	0·47	1·31	0·82	1·17						
			Oats	0·26	0·55	0·80	0·90						
			Hay	—	—	0·15	1·05						
			Greens	3·56	3·66	2·49	3·08						
			Daily Total (gross)	4·29	5·52	4·26	6·20						
B	Lilac × Rex, F_2	30	Mash	0·57	0·51	0·73	1·10						
			Oats	0·11	0·38	0·47	1·19						
			Hay	—	0·15	1·01	2·00						
			Greens	2·18	1·19	2·32	4·69						
			Daily Total (gross)	2·86	2·23	4·53	8·98						
C	Havana × Rex, F_2	50	Mash	0·342	0·435	0·922	1·202						
			Oats	0·083	0·237	0·692	0·919						
			Hay	—	—	—	—						
			Greens	1·232	1·973	3·735	5·464						
			Daily Total (gross)	1·657	2·645	5·349	7·585						
D	Havana × Rex, F_2	50	Mash	0·20	0·79	1·10	0·75	1·02	0·95	1·13	1·11	1·25	1·23
			Oats	0·09	0·30	0·61	0·52	1·09	0·67	0·94	0·82	1·15	1·21
			Hay	0·28	1·04	0·40	—	—	—	—	0·38	1·65	0·72
			Greens	0·84	2·98	3·74	8·75	8·68	7·77	8·10	6·17	6·99	9·35
			Daily Total (gross)	1·41	5·11	5·85	10·02	10·79	9·39	10·17	8·48	11·04	12·51
E	Angora (Control Mash)	21	Mash	0·42	0·81	1·22	1·47	1·19	1·34	1·25	1·37	1·42	1·42
			Oats	0·23	0·34	0·55	0·81	0·83	0·96	1·18	1·23	1·41	1·40
			Hay	0·09	—	—	—	—	0·41	0·06	0·59	1·52	—
			Greens or roots	1·48	3·92	6·58	6·36	5·58	4·79	5·45	6·17	6·00	4·58
			Daily Total (gross)	2·22	5·07	8·35	8·64	7·60	7·50	7·94	9·36	10·35	7·40
F	Angora (Linseed Mash)	21	Linseed mash	0·01	0·75	1·14	1·64	2·29	2·22	2·39	2·68	2·69	2·35
			Hay	0·10	—	—	—	—	0·42	0·34	0·58	1·55	0·08
			Greens or roots	1·96	4·03	6·56	6·70	5·98	4·75	5·70	6·22	6·01	4·33
			Daily Total (gross)	2·07	4·78	7·70	8·34	8·27	7·39	8·43	9·48	10·25	6·76
Range			Mash	0·01–0·57	0·44–1·31	0·73–1·22	0·75–1·64	1·02–2·29	0·95–2·22	1·13–2·39	1·11–2·68	1·25–2·69	1·23–2·35
			Oats	— 0·26	— 0·55	— 0·80	— 1·19	— 1·09	— 0·96	— 1·18	— 1·23	— 1·41	— 1·40
			Hay	— 0·28	— 1·04	— 1·01	— 2·00	— —	— 0·42	— 0·34	0·38–0·59	1·52–1·65	— 0·72
			Greens and roots	0·84–3·56	1·19–4·03	2·32–6·58	3·08–8·75	5·58–8·68	4·75–7·77	5·45–8·10	6·17–6·22	6·00–6·99	4·33–9·35
			Totals (Range of)	1·41–4·29	2·23–5·52	4·26–8·35	6·20–10·02	7·60–10·79	7·39–9·39	7·94–10·17	8·48–9·36	10·25–11·04	6·76–12·51

Group F received linseed mash in place of control mash and oats. The mixture was that used for brood does until 4 months and afterwards the adult maintenance linseed mash formula (Table 1, Lot L). This mash is bulky and for this reason the amount

consumed by Group F was less than the amount of mash plus oats consumed by the controls. The results slightly favoured the control ration.

Various studies have been made of food consumption to produce 1 lb. increase in weight in young rabbits (39, 88, and 161) but, since gross weight of food gives no indication of the nutrients consumed or of the efficiency of conversion, it is not thought profitable to discuss these results until further data are available.

The Swedish workers continue the rations fed at the time of weaning. At 5 months they give those intended for slaughter a fattening ration with milk which they consider very satisfactory. Its composition is shown below :—

Fattening Ration with Milk.

Hay	Oats	Oat-meal	Boiled Potatoes	Dried Milk	Total	Dry Matter	Food Units	Digestible Protein	Ash
g.	g.	g.	g.	g.	g.	g.		g.	g.
85	40	20	60*	50	255	141·8	0·107	10·32	7·77

* Raw Weight.

Morning : whole oats and water ; evening : mash of oatmeal with milk, boiled potatoes with skins and hay.

QUALITY OF PRODUCT.

Meat.—The principal British markets for table rabbits require a medium-sized carcase, well covered with muscle and without too much fat. The fat should be as white as possible, and the flesh should be free from strong feed flavours.

In order to fulfil the first demand, smaller medium breeds are popular as they provide the ideal type of carcase when pelted although larger types will reach the desired weight at a much earlier age. The ratio of carcase weight to liveweight increases from just over 50 per cent. in young rabbits to between 60 and 65 per cent. in young adults. Hence, to give a dressed carcase weight of 2½ to 3 lb., a minimum liveweight of from 4 to 5 lb. is required.

The dressed carcase yield and the proportion of edible meat in the dressed carcase partly depend on feeding. Hammond (68) has shown that the ratio of edible meat to carcase at birth is only 66 per cent. and that it increases to 82 per cent. in the adult. The better the animal is fed the higher the ratio will be. In the early stages of growth there is no difference between male and female animals, but later the female gives the higher proportion of edible carcase, chiefly because of a higher fat content. Analyses (114, 146, 179, 197 and 199) have shown that the composition of rabbit meat is similar to that of chicken and it is as easily digested (9). Protein is from 18 to 22 per cent. Fat varies widely with age, sex and diet, with a range from about 2 to about 22 per cent.

The colour of the fat also depends on diet. Indeed, it has been shown that certain strains have an inborn tendency to produce yellow fat (137, 139) but even in these the tendency can be controlled. The yellow colour is due to the pigment xanthophyll (181) which comes from green food. Rabbits whose fat is naturally white have, in their livers, an enzyme which breaks down this pigment, but rabbits with yellow fat have not. The pigment is therefore deposited in the fat. The colour is deepest (75) in rabbits that have lost condition and are lean at slaughter. It may be avoided by omitting green food from finishing rations and using mangolds instead.

The flesh of rabbits fed on grass alone tends to be dark red ; but this can also be avoided by using foods of low xanthophyll and chlorophyll content in the finishing ration.

The correct balance of the ration should be maintained during finishing. If the proportion of concentrates is too high, the carcases will be overfat. Feedingstuffs liable to impart a flavour to the flesh or fat should be avoided. Swedish advice (61) is that turnips, cabbage and cauliflower should not be used in finishing rations ; carrots, fodder beet, parsnips and potatoes should take their place ; and that fish oil and fishmeal, at least from fat fish, should not be used. But white fishmeal, to the extent of 10 per cent. of the mash, fed up to the time of killing, has not been found to taint the meat (197).

Wool and Fur.—The most convenient breed for studies of coat growth is the Angora, since its coat is clipped. The following table from Harper Adams records shows the weights of wool clipped and the quantities of food consumed by growing Angoras reared from birth to 260 days of age on (*a*) normal mixed control diet ; (*b*) control mash replaced by a popular linseed mash without grain ; (*c*) a small allowance of mash and greenstuff supplemented with goat's milk ; and (*d*) hay and green food only. The best conditioned rabbits were those on the control diet, followed by those receiving linseed mash. Group (*c*) was inferior and the rabbits fed on hay and green food only were in every way unsatisfactory.

TABLE 4.—Average Food Consumption of Young Angoras to 260 Days Old.

	Av. Live-weight at 260 Days	Dry Mash	Oats	Hay	Green-stuff or Roots	Milk	Av. weight of Clipped Wool
	lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.	lb. oz.	drams.
(*a*) Control diet .	4 14·2	19 5·7	14 8·4	4 5·4	82 11·7	—	77·98
(*b*) Linseed mash (no grain) .	4 9·0	29 8·2	—	4 15·8	84 14·2	—	75·18
(*c*) Low mash and greens, plus milk	3 15·0	14 2·8	15 8·7	10 14·9	10 4·3	7 4·1	56·80
(*d*) Hay and greens only . .	3 4·6	—	—	27 2·5	293 12·3	—	40·50

It has already been suggested that the inadequacy of rations of fresh green food might be due, at least in part, to their low energy value. Recent experimental work on sheep has shown that submaintenance rations reduce wool growth by a third (53). But the average daily calorie value of diet (*a*) above, for rabbits, calculated in the same way as the comparisons made on pp. 7–8 and taking the greenstuff as kale, is less than that of diet (*d*). Some other explanation must be sought.

Work at the same centre has shown that adult Angoras fed on the control maintenance ration gave an average yearly wool yield of 8·75 oz. and that on the linseed mash (Table 1, Lot L) the yield was 8·25 oz. When the control mash portion of the ration was replaced by bran the yearly wool yield was 7·1 oz.

Higher yields of wool have been reported under carefully controlled experimental conditions at the Kiel-Steenbek centre on the ration described on p. 20. In these tests the does produced much higher average yields than the bucks : bucks, 9·4 oz. in the first year and 12·7 oz. in the second ; does, 11·0 and 14·9 oz.

Various special feeds and special supplements have been recommended to improve the quality of wool and fur. Paice says that milk improves the gloss of the wool and doubles the fat content of its fibre. Pickard (140, 141, 142) found that special supplements of calcium alone or mineral mixtures depressed wool growth but that cod liver oil, 3 drops daily, 6 days a week, increased the clip by 13 per cent. It also counteracted the depressant effect of the calcium supplement. Wirth (200) feeds both calcium and cod liver oil, and other workers

(5, 31) claim good results from using oilseeds in the ration for fur rabbits, ranking linseed oil meal as superior to soya bean or peanut.

In view of these results and the beneficial effects on general condition and wool growth claimed by Italian workers for wheat germ oil (p. 10), it would be of value to know whether oil, in all forms, stimulates wool growth, or, alternatively, whether the calorie value of the oil supplements is of importance.

The importance of an adequate supply of water for wool production and of salt for maintaining a healthy condition of the skin have already been noted. American workers (169) have found that rabbits, when they are moulting, consume slightly more salt than usual.

Reference has also been made to the fact that supplements of iodine have been found beneficial. Cunningham (44) showed that black fur contains more copper than white fur and Gorter (58) that deficiency of copper will cause depigmentation of fur. Deficiency of copper is, however, not likely to occur with mixed rations.

ECONOMICS OF RABBIT PRODUCTION.

Economy of Food Conversion.—A number of estimates have been made of the total food consumption required to produce a given weight of edible meat. Tullis (166) estimates that usually from 6 to 8 lb. dry weight of food is required to produce 1 lb. of flesh, but under favourable conditions, consumption may be reduced to just over 4 lb. These estimates give ratios of food dry matter to edible dry matter varying from the most favourable of 16 : 1 to 32 : 1. From records of the annual production of 5711 does in Los Angeles (26) it has been estimated that 3·5 lb. grain and mash, 2·3 lb. hay and 2·3 lb. greens are required per lb. of rabbit successfully reared under that system. This would represent roughly 5 lb. dry matter and, assuming carcase weight to be 65 per cent. of liveweight, 77 per cent. of the carcase to be edible and the edible dry matter to be 25 per cent., the ratio of food to edible dry matter would be roughly 40 : 1. This high estimate of 40 : 1 includes the total overhead cost of maintenance of the colony, that is including the breeding stock. In calculating the efficiency of conversion for cows, pigs and beef cattle, it is not customary to include the expense of maintaining the total herd. Calculations from the data in the next table for medium-sized rabbits, including only the food consumption of the rabbits slaughtered for meat, give ratios of from 20 to 30 : 1. In these tests the amount of concentrates consumed per lb. live weight gain was less than in American practice and varied from 2·9 lb. down to 1·9 lb.

TABLE 5.

Average Food Consumption to Killing Age at 4 Months (oz.). Medium-Sized Rabbits.

Group	Mash	Oats	Hay	Greens or Roots	Total Dry Matter	Food Dry Matter to Total Dry Matter
A	105·56	70·28	33·60	358·12	3·54	28
B	81·48	60·20	88·48	290·64	3·59	30
C	81·23	54·07	—	347·31	2·45	20
D	79·52	42·56	48·16	456·68	3·18	25
E	109·76	54·04	2·52	513·52	3·62	29
F	99·12	—	2·80	539·00	2·98	24

Compared with larger domestic animals, the rabbit is therefore relatively inefficient but compares favourably with the domestic fowl. To produce 1 lb. of human food dry matter, the following quantities of feedingstuffs dry matter are required : milk cow 5, pig 8, hen

(eggs) 15, beef cattle 20, rabbit 20–30, fowl (meat) 32. It should be remembered that, in the rabbit, fur production is often primary and meat only a subsidiary product.

Cost and Profit of Production.—It is impossible to make any generally valid statements on costs and profits since the prices of foodstuffs may vary from zero, when weeds and waste are used, up to high levels if expensive concentrates, milk, and vegetables like carrots or cauliflower, are extensively fed. It was found that when commercial practice was applied at Harper Adams College the cost of food for rabbits ready to slaughter for meat at 3 months of age was 5d. to 7d. and at 4 months of age it was 8d. to 1s. when kept in hutches. For fur breeds, fed to 7 months of age for pelts and flesh, the cost was proportionately greater, 1s. 5d. to 2s.

Carcases usually sell at from 8d. to 1s. per lb., according to the quality, giving a price per carcase of from 2s. to 3s. Prices have risen much higher since the war started and the carcase price has recently been as high as 4s. 6d. Pelts from fur breeds usually sell at 4s. to 5s.; Rex skins at 5s. to 7s. and some of extra fine quality make as much as 9s. to 10s. 6d. each. On the average, the food cost of the pelt rabbit will be fully covered by the price obtained for the carcase and that of the skin will represent gross profit.

Swedish costing accounts based on the rearing by each doe of 4 litters of 6 annually, each litter fed to 6 months of age, showed that food costs were 50 per cent., and other expenses (carriage, packing, rent, depreciation and interest and wages) 33 per cent. of the total income, leaving a net profit of 17 per cent.

The following table shows an earlier cost and profit balance for Angora wool rabbits up to 2 years of age at Harper Adams College (187).

TABLE 6.

MARGIN OF INCOME OVER FOOD COST: ANGORA WOOL PRODUCTION.

Age in Days	Average Wool Yield per Rabbit	Average Price per lb. of Wool	Income by Wool Sales	Food Cost per Rabbit	Balance over Food Cost	Food Cost per lb. of Wool Grown	Margin of Income over Food Cost per lb. of Wool Grown
	oz.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
0–730	12·48	26 0½	20 3¾	10 9	9 6¾	13 9¼	12 3¼
261–730	8·93	26 0½	14 6½	6 10¾	7 7¾	12 ·4¼	13 8¼

It will be seen that when the average price of wool was 26s. per lb., the average profit was almost 90 per cent. of the food cost, and that even in the first 260 days there was a profit of 33 per cent. over the food cost of rearing the rabbit.

SUMMARY.

The rearing of rabbits for meat and fur is of considerable economic importance. The rabbit has the outstanding advantages that when required to do so it can be used as a means of converting waste products and vegetation not used as human food into food of high biological value for man and that it produces fur at the same time.

Few laboratory studies of the rabbit's nutritional requirements have been made but certain general facts have been established. The rabbit requires fibre in its diet but does not digest fibre efficiently and too much fibre reduces the value of a ration. It does not generally appear to thrive on diets of fresh green food alone, nor on hay and greens alone when kept in hutches, nor on diets without green food. Rabbits can be grazed on greenstuff alone when

the herbage is young and plentiful. Mixed diets give rapid growth and production. When high growth and reproduction rates are desired, special supplements of protein and minerals are necessary for does and young animals. Milk and fishmeal provide both.

Water and a salt brick should always be provided.

The foods commonly used for rabbits include greens and roots in great variety, hay and cereals with additional protein and oil foods for high condition. Feeding systems may easily be adjusted to utilise any waste products and fodders available locally. The proportions of green to dry food may vary widely according to available supplies. Details of many rations are presented and, from these, rations may be selected, or modifications made, to suit local conditions.

Compared with the milk cow, or larger meat producing animals, the rabbit is relatively inefficient in the conversion of plant food to meat, but its advantage lies in its adaptability to use what would otherwise go to waste. Furthermore it can be reared in practically every garden in both town and country, where there is no room for larger stock. The price of the carcase, as meat, will commonly cover the food cost of rearing and the price of the pelt be gross profit. In the case of table rabbits the food costs are much lower, owing to the earlier killing age.

From research centres further information is required on the digestibility of different foodstuffs and rations by rabbits and the consumption of total digestible nutrients in relation to rate of growth. With these studies observations should be included on the effect of adding calcium to and providing salt with rations considered to be adequate, but unsupplemented with these minerals.

BIBLIOGRAPHY.

(1) Abderhalden, E. *Hoppe-Seyler's Ztschr.*, 1899, **26,** 487.
(2) Agduhr, E. *Acta paediat.*, 1926, **5,** 319; 1926, **6,** 165; 1928, **7,** 289.
(3) Arbuthnot, A. *Harper Adams Utility Poultry J.*, 1927–28, **13,** 578.
(4) Ashbrook, F. G. "Rabbits for Food and Fur," N.Y., Orange Judd, 1930, 81.
(5) Ashbrook, F. G. *J. Tech. Assoc. Fur Indust.*, 1934, **5,** 39.
(6) Ashbrook, F. G. and Meyer, J. W. *U.S. Dept. Agric.* Bi-1066, 1930, 2.
(7) Ashbrook, F. G. and Kellogg, C. E. *U.S. Dept. Agric. Farmers' Bull.* No. 1730, 1934, 20.
(8) Augé-Laribé, M. and Pinot, P. "Agriculture and Food Supply in France," New Haven, Yale Univ. Press, 1927, 89.
(9) Baglioni, S. *Schlussber. VI Weltgeflügelkongresses*, 1936, **3,** 180.
(10) Barritt, J., King, A. T. and Pickard, J. N. *Biochem. J.*, 1930, **24,** 1061.
(11) Barron, N. S. *Harper Adams Utility Poultry J.*, 1927–28, **13,** 561.
(12) Baumann, E. J. *J. Biol. Chem.*, 1931, **92,** lxxx. *Proc.*
(13) Bell, F. R. "Green Foods for Rabbits and Cavies," Bradford, Watmoughs, 1928.
(13*a*) Benedict, F. G. *Carnegie Inst. Washington Pub.* No. 503, 1938.
(14) Bensley, B. A. "Practical Anatomy of the Rabbit," Philadelphia, Blakiston, 1926, 77.
(15) Bertelli, E. *Monthly Bull. Agric. Sci. Practice*, 1936, **27,** 453 T.
(16) Bischoff, F., Sansum, W. D., Long, M. L. and Evans, R. D. *J. Nutrition*, 1932, **5,** 403.
(17) Brett, W. "Smallholder Encyclopædia," London, Pearson, 1934, 393.
(18) *British Fur Trade*, 1930, July.
(19) ,, ,, ,, 1936, June, **19,** 9.
(20) Brody, S. *Rep. Conference on Energy Metabolism, Pennsylvania*, June, 1935, 12.
(21) Brown, W. H. and Greene, H. S. N. *Trans. Assoc. Amer. Physicians*, 1933, **48,** 248.
(22) Brüggemann, H. *Biedermanns Zentralbl.* [*B*] *Tierernährung*, 1937, **9,** 374.

(23) BRUMWELL, W. "The Chinchilla Rabbit," Bradford, Watmoughs, 1930, 62.
(24) BUNGE, G. "Lehrbuch der physiologische und pathologische Chemie," 1898, 4th ed., 118.
(25) BURKY, E. L. *J. Lab. Clin. Med.*, 1932, **18,** 189.
(26) BURLINGAME, B. B. and MILLAR, J. L. *Agric. Exten. Serv., Univ. Calif. and U.S. Dept. Agric.*, 1937.
(27) BUTTERFIELD, H. M. *Amer. Rabbit Rec.*, 1929, Oct. 3.
(28) ,, ,, *Ibid.*, Nov. 3.
(29) BUTTERFIELD, H. M. and LLOYD, W. E. *Calif. Exten. Agric. Serv. Circ.* No. 9, 1927, 25. (Revised ed., 1935, 38.)
(30) CANADIAN DEPT. AGRIC. "Feeding Rabbits," Dept. Agric. Leaflet, Ottawa, 1935.
(31) CASPE, J., ASHBROOK, F. G. and KELLOGG, C. E. *J. Tech. Assoc. Fur Indust.*, 1934, **5,** 70.
(32) CASTLE, W. E. *J. Exp. Zoöl.*, 1929, **53,** 421.
(33) ,, ,, *Carnegie Inst. Washington Pub.* No. 320, 1922.
(34) CHARON, A. J. "Lapins," Lapereaux & Cie, Paris, Librairie Rustique, 1933, 148.
(35) CHESNEY, A. M., CLAWSON, T. A. and WEBSTER, B. *Bull. Johns Hopkins Hosp.*, 1928, **43,** 261; 278; 291.
(36) CHRISTIAN, M. I. *Harper Adams Utility Poultry J.*, Rabbit Suppl., 1935–36, **21,** 539.
(37) CHUNG, H. L. *Hawaii Agric. Exten. Bull.* No. 12, 1931, 15.
(38) CONNOLLY, R. A. and CARD, C. G. *Quart. Bull. Mich. Agric. Exp. Stat.*, 1931, **14,** 77.
(39) CONNOLLY, R. A. and CARD, C. G. *Ibid.*, 1932, **14,** 146.
(40) (COOK, G. A.) *J. Counc. Sci. Indust. Res. Austral.*, 1932, **5,** 196.
(41) CORRIE, F. E. "Iodine for Livestock," 1928.
(42) CRAMPTON, E. W. *Empire J. Exp. Agric.*, 1934, **2,** 337.
(43) CRAMPTON, E. W. and FINLAYSON, D. A. *Ibid.*, 1935, **3,** 331.
(44) CUNNINGHAM, I. J. *Biochem. J.*, 1931, **25,** 1267.
(45) DAKIN. (Cited by Halnan (64).)
(46) DAVIES, C. J. "Rabbits for Fur and Flesh," London, Country Life, 1918, 98.
(47) DAVIES, W. L. "Chemistry of Milk," London, Chapman & Hall, 1936, 7.
(48) DEARBORN, N. *U.S. Dept. Agric. Farmers' Bull.* No. 1090, 1920, 17.
(49) DESMARÁS, C. L. *Minist. Agric., Buenos Aires, Bull.* No. 832, 1931, 23.
(50) ELTON, C. and SWYNNERTON, G. *Canadian Field-Naturalist*, 1936, **50,** 71.
(51) FANGAUF, R. and IMMENKAMP, G. *Arch. Geflügelk.*, 1938, **12,** 185.
(52) *Flugblätter deutsch. landwirtsch. Gesellsch., Sonderausschuss Kaninchenzucht*, No. 115, 1932.
(53) FRASER, A. H. H. and NICHOLS, J. E. *Empire J. Exp. Agric.*, 1934, **2,** 9; 1935, **3,** 75.
(54) "Fur Producing Rabbits," Bradford, Watmoughs, 4th ed., 1929.
(55) GOLDBLATT, H. and MORITZ, A. R. *J. Exp. Med.*, 1925, **42,** 499.
(56) GOMPEL, M., HAMON, F. and MAYER, A. *Ann. Physiol. Physicochim. biol.*, 1936, **12,** 471.
(57) GOMPEL, M., HAMON, F. and MAYER, A. *Ibid.*, 504.
(58) GORTER, F. J. *Nature*, 1935, **136,** 185.
(59) GREEN, D. M. *U.S. Dept. Agric. Leaflet* No. 4, 1927, 4.
(60) GRUNIGEN, F. V. *Die Tierwelt*, 1933, **43,** 1198; 1221; 1259; 1318; 1346.
(61) HAGELIN, K. F. "Kött och Pälskaniner Handbok i Rationell Uppfödning." Stockholm, Kooperativa Förbundets Bokförlag, 1935, 52.
(62) HALL, E. M. and MACKAY, E. M. *Amer. J. Pathol.*, 1931, **7,** 327.
(63) ,, ,, ,, ,, *Ibid.*, 343.
(64) HALNAN, E. T. *Fur and Feather*, 1927, Feb. 11th, 174.
(65) ,, ,, *J. Minist. Agric. Engl.*, 1925, **32,** 363.
(66) HAMILTON, W. J. (Jr.). *New York State Coll. Agric., Cornell Exten. Bull.* No. 284, 1934, 8.
(67) HAMMOND, J. *J. Exp. Biol.*, 1934, **11,** 140.

(68) HAMMOND, J. "Rabbits." Year Book of the National Rabbit Council, Edinburgh, 1931, 32.
(69) HAMMOND, J. *Wiss. Ber. VI Weltgeflügelkongresses*, 1936, **1,** 153.
(70) HAMMOND, J. and MARSHALL, F. H. A. "Reproduction in the Rabbit," Edinburgh, Oliver & Boyd, 1925.
(71) HANGLIN, P. J. *Harper Adams Utility Poultry J.*, 1936–37, **22,** 524.
(72) HARRIS, L. J. and INNES, J. R. M. *Biochem. J.*, 1931, **25,** 367.
(73) HARRIS, L. J. and STEWART, C. P. *Ibid.*, 1929, **23,** 206.
(74) HERMAN, S. and ZENTNER, M. *Arch. exp. Pathol. Pharmakol.*, 1933, **172,** 5.
(74*a*) HILL, L. *M.R.C. Spec. Rep. Ser.* No. 52, London, H.M.S.O., 1920.
(75) HIRZEL, R. *J. Agric. Sci.*, 1935, **25,** 541.
(76) HOGAN, A. G. and JOHNSON, S. R. *Missouri Agric. Exp. Stat. Bull.* No. 370, 1936, 22.
(77) HOGAN, A. G. and JOHNSON, S. R. *Proc. Soc. Exp. Biol. Med.*, 1936, **35,** 217.
(78) HOGAN, A. G. and RITCHIE, W. S. *Missouri Agric. Exp. Stat. Res. Bull.* No. 219, 1934.
(79) HOLE, A. *Harper Adams Utility Poultry J.*, 1934–35, **20,** 603.
(80) HOLMQUIST, A. G. *Ztschr. ges. exp. Med.*, 1934, **93,** 370.
(81) HOUSE, C. A. and WATSON, A. "Rabbits and All About Them," Bradford, Watmoughs, 4th ed., 1927, 19.
(82) HU, C. K., ROSAHN, P. D. and GREENE, H. S. N. *Proc. Soc. Exp. Biol. Med.*, 1934, **31,** 1010.
(83) IBSEN, H. L. *Science*, 1927, **66,** 509.
(84) INNES, J. R. M. *Director's Rep. Inst. Animal Pathol., Cambridge*, 1929–30, 102.
(85) INNES, J. R. M. *Proc. Roy. Soc. Med.*, 1931, **24,** 1368.
(86) INNES, J. R. M. and HARRIS, L. J. *Director's Rep. Inst. Animal Pathol., Cambridge*, 1929–30, 92.
(87) KELLOGG, C E. *U.S. Dept. Agric., Yearbook Agric.*, 1939, 891.
(88) ,, ,, *U.S. Dept. Agric.* Bi-1294, 1933.
(89) ,, ,, *Ibid.*, Bi-1304, 1933.
(90) ,, ,, *Ibid.*, Circ. No. 410, 1936.
(91) ,, ,, *Ibid.*, Wild-life Leaflet B.S.-31, 1936.
(92) ,, ,, *Ibid.*, B.S.-65, 1936.
(93) KLIMMER, M. "Scientific Feeding of the Domestic Animals," London, Ballière, Tindall & Cox, 1923, 214.
(94) KNIERIEM, W. v. *Landwirtsch. Jahrb.*, 1898, **27,** 521.
(95) KOPEĆ, S. *Anat. Rec.*, 1924, **27,** 95.
(96) LEAVER, T. *Harper Adams Utility Poultry J.*, 1933–34, **19,** 559.
(97) LEE, R. C. *J. Nutrition*, 1939, **18,** 473; 489.
(98) LEGENDRE, G. *Rev. Zootech.*, 1934, **13,** 223.
(99) ,, ,, *Ibid.*, **14,** 357.
(100) LENTHALL, G. *Harper Adams Utility Poultry J.*, 1932–33, **18,** 651.
(101) LONG, M. L. and BISCHOFF, F. *J. Nutrition*, 1930, **2,** 245.
(102) MACDONALD, A. J. *Harper Adams Utility Poultry J.*, 1935–36, **21,** 531.
(103) MACDOWELL, E. C. and CASTLE, W. E. *Carnegie Inst. Washington Pub.* No. 196, 1914.
(104) MADSEN, L. L., MCCAY, C. M. and MAYNARD, L. A. *Cornell Agric. Exp. Stat. Mem.* No. 178, 1935.
(105) MAGLIANO, A. *Atti V Congresso mondiale Pollicoltura* (1933), 1934, **3,** 513.
(106) MAIOCCO, F. *Wiss. Ber. VI Weltgeflügelkongresses*, 1936, **2,** 251.
(107) MANGOLD, E. *Nutrit. Absts. Rev.*, 1934, **3,** 647.
(108) MARINE, D., BAUMANN, E. J. and CIPPRA, A. *Proc. Soc. Exp. Biol. Med.*, 1929, **26,** 822.
(109) MCCARRISON, R., SANKARAN, G. and MADHAVA, K. B. *Indian J. Med. Res.* 1933, **20,** 723.
(110) MCDOUGALL, J. B. "Angoras in Colonies," Aylesford, Brit. Legion Press, 1932.
(111) MCDOUGALL, J. B. *Riv. Coniglicoltura*, 1935, **7,** No. 7, 12.
(112) MCISAAC, P. *Brit. J. Exp. Biol.*, 1928, **5,** 233; 242; 248.

(113) McKenny, F. D. *U.S. Dept. Agric.* Bi-1286, 1933.
(114) McMillin, H. R. *J. Home Econ.*, 1931, **23,** 1149.
(115) Meek, M. W. "Fur Rabbits," 2nd ed., 1927, 99.
(116) Mellanby, M. *M.R.C. Spec. Rep. Ser.* No. 153, London, H.M.S.O., 1930.
(117) Mellanby, M. and Killick, E. M. *Biochem. J.*, 1926, **20,** 902.
(118) Middleton, A. D. *J. Animal Ecol.*, 1934, **3,** 231.
(119) Minchin and Matthews. "The Book of the Angora," Hereford, Hereford Times, 1931, 22.
(120) Ministère de l'Agriculture. "Le Lapin à Fourrure," Brussels, 1927.
(121) Morgulis, S. and Spencer, H. C. *J. Nutrition*, 1936, **11,** 573.
(122) Moritz, A. R. and Krenz, C. *Ibid.*, 1930, **2,** 257.
(123) Morris, S. *Nutrit. Absts. Rev.*, 1936, **6,** 273.
(124) Murray, A. J. *J. Agric. Sci.*, 1921, **11,** 258.
(125) Nachtsheim, H. "Das Rexkaninchen und seine Bedeutung für die Pelztierzucht," Leipzig, Heber, 1928.
(126) Nachtsheim, H. *Verhandl. I. Internat. Kaninchenzüchter Kongresses, Leipzig*, 1930, 211.
(127) Nelson, V. E. and Lamb, A. R. *Amer. J. Physiol.*, 1920, **51,** 530.
(128) Nelson, V. E., Lamb, A. R. and Heller, V. G. *Amer. J. Dis. Child.*, 1922, **223,** 518.
(129) Nelson, V. E., Lamb, A. R. and Heller, V. G. *Amer. J. Physiol.*, 1922, **59,** 335.
(130) Norris, A. D. *Province of Brit. Columbia Poultry Circ.* No. 29, 1928.
(131) Olney, J. F. *J. Amer. Vet. Med. Assoc.*, 1928, **73,** 631.
(132) Paice, N. *Fur and Feather*, 1927, Feb. 4th, 141.
(133) ,, ,, *Ibid.*, 1928, Mar. 2nd, 296.
(134) Parkhurst, R. T. *Progress Rep., Nat. Inst. Poultry Husb. Bull.* No. 5, 1931, 51.
(135) Passmore, R. *Biochem. J.*, 1935, **29,** 2469.
(136) Paton, D. N. and Orr, J. B. "Essentials of Veterinary Physiology," Edinburgh, W. Green & Son, 3rd ed., 1920, 636. (Quoting Bunge.)
(137) Pease, M. *Harper Adams Utility Poultry J.*, 1928–29, **14,** 574.
(138) ,, ,, *J. Genetics*, 1928, **20,** 261.
(139) ,, ,, *Ztschr. indukt. Abstammungs- u. Vererbungsl.* Suppl. II, 1928.
(140) Pickard, J. N. *Scot. J. Agric.*, 1928, **11,** 344.
(141) ,, ,, *Harper Adams Utility Poultry J.*, 1928–29, **14,** 8.
(142) ,, ,, *Ibid.*, 420.
(143) ,, ,, "Rabbit Keeping," London, H.M.S.O., 1932.
(144) Pickard, J. N. and Crew, F. A. E. "Scientific Aspects of Rabbit Breeding," Bradford, Watmoughs, 1931, 98.
(145) Pizzi. (Cited by Halnan (64).)
(146) Plimmer, R. H. A. "Analyses and Energy Values of Foods," London, H.M.S.O., 1921, 241.
(147) Pope, C. *Harper Adams Utility Poultry J.*, 1933–34, **19,** 563.
(148) Prjanischnikow, N. D. and Tomme, M. F. *Biedermanns Zentralbl.* [*B*] *Tierernährung*, 1936, **8,** 104.
(149) Punnett, R. C. and Bailey, P. G. *J. Genetics*, 1918, **8,** 1.
(150) Raymond, L. C. *Canad. J. Res.* [*C*], 1936, **14,** 394.
(151) Rettger, L. F., Hull, T. G. and Sturgess, W. S. *J. Exp. Med.*, 1916, **23,** 475.
(152) Richardson, E. C. "Brit. Fur Rabbit Soc. Book," 1925, 101.
(153) Richter, K. *Wiss. Ber. VI Weltgeflügelkongresses*, 1936, **2,** 261.
(154) Robb, R. C. *Brit. J. Exp. Biol.*, 1929, **6,** 293.
(155) Roberts, E. and Dawson, W. M. *Illinois Agric. Exp. Stat. Bull.* No. 413, 1935.
(156) Robertson, G. and Lee, W. *Canad. Dept. Agric. Bull.* No. 28, Revised Ed., 1929, 10.
(157) Schioppa, L. *Ztschr. Vitaminforsch.*, 1936, **5,** 22.
(158) Section of Fur Resources. *U.S. Dept. Agric. Wild-life Res. Leaflet*, B.S.-28, 1925.
(159) Smith, E. B. "Fur Rabbits for Profit."

(160) TANZER, E. "Das Angorakaninchen," Hannover, Schäfer, 1932, 95.
(160*a*) TAYLOR, E. L. *Vet. Rec.*, 1940, **52,** 259.
(161) TEMPLETON, G. S. *U.S. Dept. Agric., Wild-life Res. Leaflet,* B.S.-85, 1937.
(161*a*) ,, ,, *U.S. Dept. Agric.* B.S.-102, 1938.
(162) THOMPSON, W. C. *New Jersey Agric. Exp. Stat., Hints to Poultrymen,* 1930, **18,** No. 7.
(163) TILMANNE, H. M. *Rep. Proc. IVth World's Poultry Congress,* 1930, 941.
(164) TOCHER, J. F. *Scot. J. Agric.*, 1927, **10,** 408.
(165) TOMME, M. and LORIA, K. *Advance of Zootechnical Sci.*, 1935, **1,** 234.
(166) TULLIS, D. R. *Fur and Feather,* 1937, Mar. 19th, 187.
(167) TURNER, W. A., MEIGS, E. B. and CONVERSE, H. T. *U.S. Dept. Agric.* B.D.I.M.-721, 1936.
(168) VOINOV, D. I. "Lenin All-Soviet Acad. Agric., Sci. Res. Inst. Rabbit Breeding," 1933.
(169) VORHIES, C. T. and TAYLOR, W. P. *Arizona Agric. Exp. Stat. Bull.* No. 49, 1933, 541.
(170) WALLER, E. "Beveren Club Book," 1924, 61.
(171) WALWORTH, G. *Fur and Feather,* 1927, Feb. 25th, 233; Mar. 4th, 265.
(172) WASHBURN, F. L. *Minnesota Agric. Exten. Div., Spec. Bull.* No. 37. (Revised ed. 1919.)
(173) WASHBURN, F. L. "The Rabbit Book," Philadelphia, Lippincott, 1920, 97.
(174) WATSON, A. "How to Feed Rabbits," Bradford, Watmoughs.
(175) WATSON, C. J. and GODDEN, W. *Empire J. Exp. Agric.*, 1935, **3,** 346.
(176) WATSON, S. J. and HORTON, E. A. *Ibid.*, 1936, **4,** 25.
(177) WEISKE, H. *Landwirtsch. Versuchs-Stat.*, 1894, **43,** 207.
(178) WENDT, G. V. *Harper Adams Utility Poultry J.*, 1931–32, **17,** 72.
(179) *Western Washington Exp. Stat. Bull.* No. 8, Spec. Ser., 1922.
(180) WESTRA, J. J. *Amer. J. Physiol.*, 1933, **105,** XCVIII. *Proc.*
(181) WILLIMOT, S. G. *Biochem. J.*, 1928, **22,** 1057.
(182) WILSON, W. K. *Fur and Feather,* 1932, July 1st, 2.
(182*a*) ,, ,, *Minist. Agric. and Fish. Bull.* No. 50, 2nd Ed., 1940.
(183) ,, ,, *Harper Adams Utility Poultry J.*, 1927–28, **13,** 581.
(184) ,, ,, *Ibid.*, 1928–29, **14,** 172.
(185) ,, ,, *Ibid.*, 313.
(186) ,, ,, *Ibid.*, 366.
(187) ,, ,, *Ibid.*, 1930–31, **16,** 579.
(188) ,, ,, *Ibid.*, 1931–32, **17,** 567.
(189) ,, ,, *Ibid.*, 1933–34, **19,** 567.
(190) ,, ,, *Ibid.*, 1936–37, **22,** 515.
(191) ,, ,, *J. Heredity,* 1936, **27,** 127.
(192) ,, ,, *Nature,* 1935, **136,** 434.
(193) ,, ,, *Rep. Proc. IVth World's Poultry Congress,* 1930, 949.
(194) ,, ,, *Minist. Agric. and Fish. Bull.* No. 73, 1934, 7.
(195) WILSON, W. K. *Verhandl. I. Internat. Kaninchenzüchter Kongresses, Leipzig,* 1930, 191.
(196) WILSON, W. K. *Wiss. Ber. VI Weltgeflügelkongresses,* 1936, **2,** 273.
(197) WILSON, W. K. and BOTHAM, G. H. *Harper Adams Utility Poultry J.*, 1933–34, **19,** 441.
(198) WILSON, W. K. and DOWNHAM, K. D. *Vet. J.*, 1932, **88,** 263.
(199) WILSON, W. K. and MORRIS, S. *J. Agric. Sci.*, 1932, **22,** 453.
(200) WIRTH. *Riv. Coniglicoltura,* 1933, **5,** No. 3, 17.
(201) *VIth World's Poultry Congress, Catalogue,* 1936, 81.

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